Exhibit 5

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Counts, et al. v. General Motors LLC

Expert Report of
Ryan Harrington

Prepared for

Kirkland & Ellis, LLP

Prepared by

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1 QUALIFICATIONS

I, Ryan J. Harrington, am a Principal at Exponent, an engineering and scientific consulting firm, where I focus on vehicle engineering. I have more than 20 years of experience working in the automotive industry and the federal government. Examples of my prior work include the analysis and development of federal regulations, policies, and standards, including fuel economy and emissions rulemakings and motor vehicle safety standards. I have authored multiple papers and delivered numerous presentations on issues related to emerging transportation technologies, motor vehicle safety systems, and fuel efficiency and emissions policies. I hold a Master of Science in Automotive Engineering from the University of Michigan, Ann Arbor and a Bachelor of Science in Mechanical Engineering from the University of Nebraska. In 2008, I was the recipient of the U.S. Department of Transportation (DOT) Secretary's Gold Medal Award, the Department's highest award.

Prior to joining Exponent, from 2007 to 2017, I worked at the U.S. DOT Volpe National Transportation Systems Center (Volpe Center) where I was Chief of the Technology Innovation and Policy Division. In this role, I led a cross-functional team of scientists, engineers, and analysts focused on emerging transportation technologies including automated vehicles, connected vehicles, connected/smart cities, and big data. I was invited to the White House Office of Science and Technology Policy's Executive Leadership Retreat to identify key priorities and challenges related to the deployment of automated vehicles.

Prior to my position as Chief of Technology at the Volpe Center, I worked as a Senior Engineer at the Volpe Center. In that position, I led a team that performed engineering analyses and developed fuel-savings, cost, deployment rates and applicability assumptions for light-duty and heavy-duty vehicle technologies, which were incorporated into the National Highway Traffic Safety Administration's (NHTSA) Corporate Average Fuel Economy (CAFE) standard setting compliance and effects modeling. I also presented technology analyses at senior level briefings for the White House Office of Management and Budget (OMB), the DOT, the Environmental Protection Agency (EPA), the California Air Resources Board (CARB), and the National Academy of Sciences (NAS). I represented the DOT and participated in executive level meetings with vehicle manufacturers; engine, transmission, and component suppliers; and industry trade associations. I was recognized by the President in the Oval Office for my technical contributions to the development of the model years 2017-2025 CAFE standards.

From 2004 to 2007, I was a Technical Support Manager at Cummins Inc., where I led Six Sigma on-road fuel economy testing and improvement projects, analyzed customer requirements, performed root cause analyses for diesel engines, proposed diesel engine/drivetrain changes to improve the fuel efficiency of long-haul trucks, and conducted fuel efficient driver training.

In my role as a Vehicle Test Operations Manager at Environmental Testing Corporation, I coordinated and managed Federal Test Procedure (FTP) dynamometer emissions testing by interfacing with customer engineers and managing technicians.

I am a member of the Society of Automotive Engineers (SAE) and a volunteer design judge for its Formula Hybrid Competition. I am also a peer reviewer at the Department of Energy's annual merit review.

2 ASSIGNMENT

I have been retained by Kirkland & Ellis LLP, counsel for General Motors LLC (GM) in the above-referenced action to provide expert testimony in this matter and to review and respond to certain assertions made in the expert report of Juston Smithers (Smithers Report) and in the expert report of Kirill Levchenko (Levchenko Report). In particular, I have been asked to:

- Provide a description of the emissions control systems in the model year 2014 and 2015 Chevrolet Cruze Diesel, and GM's disclosures to the EPA regarding these systems;
- Evaluate Mr. Smithers' portable emission measurement system (PEMS) and dynamometer testing and corresponding analyses of emissions results of the diesel and gasoline Cruze vehicles he tested, as well as the conclusions Mr. Smithers draws from those data and analyses;
- Assess Dr. Levchenko's analysis of the EDC software code as programmed in the 2014 Chevrolet Cruze Diesel vehicle and evaluate the opinions he draws from such analysis;
- Describe the relevant vehicle emissions standards, including standards for light-duty vehicles and certification testing protocols; and
- Describe the context of these emissions standards and control systems, including recent developments in "clean diesel" technology and investigations into "defeat devices."

My opinions are based on my education and training in mechanical and automotive engineering including: federal government experience setting fuel economy and emissions standards; experience working in the automotive and commercial vehicle industries (including for a diesel engine manufacturer); my review of materials, and analysis performed in this case. I hold each of my opinions expressed in this report to a reasonable degree of engineering and scientific certainty.

The data, analysis, and conclusions included in this report are based on ongoing review of documents and other materials available to me. If additional information becomes available, this report may be amended or supplemented.

In 2020, Exponent charges $450 per hour for my time. A copy of my curriculum vitae, which provides additional details of my professional background, is attached as Appendix A to this report. Appendix B contains my testimony history for the past four years. Appendix C contains a list of materials I considered in connection with this case.

3 SUMMARY OF PLAINTIFFS' CLAIMS

Plaintiffs, individually and on behalf of all others similarly situated, brought this suit on behalf of a class of current and former owners or lessees of GM's Model Year 2014 and Model Year 2015 Chevrolet Cruze diesel vehicles (the Subject Vehicles).[1]

I understand that Plaintiffs allege, among other things, that the Subject Vehicles, "had defective emissions controls," "emitted pollutants at a higher level than gasoline powered vehicles," "emitted pollutants higher than a reasonable consumer would expect," "emitted unlawfully high levels of pollutants such as nitrogen oxides (NO_x) and were non-compliant with EPA emission requirements" including that "emissions materially exceeded applicable emissions limits in real world driving conditions," and that GM "intentionally concealed that the NO_x reduction system…turns off or is limited during normal driving conditions."[2]

The Smithers[3] and Levchenko[4] Reports reach the following conclusions in support of these claims, among others:

- The Subject Vehicles' NO_x emissions are significantly higher than the gasoline version;[5]
- The Subject Vehicles' NO_x emissions are high relative to EPA emissions standards across a range of "real world" driving conditions;[6] and
- The Subject Vehicles were designed with multiple defeat devices and emissions derating strategies that were not fully disclosed to regulators.[7]

1 First Amended Class Action Complaint, Jason Counts, et al., v. General Motors LLC, et al., Case No. 1:16-CV-12541-TLL-PTM, filed June 11, 2018. Hereafter referred to as the Complaint.

2 Complaint, ¶¶ 24, 309.

3 Expert Report of Juston Smithers, *Jason Counts, et al., v. General Motors LLC, et al.*, Civ. Action No: 16-cv-12541-TLL-PTM, October 28, 2019. Hereafter referred to as the "Smithers Report."

4 Expert Report of Kirill Levchenko, *Jason Counts, et al., v. General Motors LLC, et al.*, Civ. Action No: 16-cv-12541-TLL-PTM, October 28, 2019. Supplemental Expert Report of Kirill Levchenko, February 5, 2020; Corrected Expert Report of Kirill Levchenko, May 12, 2020. Hereafter referred to collectively as the "Levchenko Report." Page and paragraph citations are to Dr. Levchenko's original report.

5 Smithers Report, ¶¶ 304, 308.

6 Smithers Report, ¶ 20.

7 Smithers Report, ¶ 309. Levchenko Report, ¶ 5.

4 EXECUTIVE SUMMARY AND SUMMARY OF OPINIONS

4.1 Executive Summary

Regulatory agencies have established a formal, detailed, and specific process for certifying that light-duty vehicles sold in the United States meet the required emissions standards. Testing to certify a vehicle according to the U.S. Environmental Protection Agency's (EPA) Tier 2 emissions standards is conducted in a carefully controlled laboratory setting using set driving schedules (known as test cycles) on a dynamometer, not through on-road emissions measurements. There are different test cycles for different driving conditions, including: city, highway, high acceleration and high speed, and high temperature with air conditioner use. Dynamometer testing procedures are inherently prescriptive and require scrupulous vehicle, fuel, and test equipment preparation. This is to ensure accuracy and repeatability of emissions test results.

Similar to fuel economy, vehicle emissions, including NO_x, are variable and depend on many factors related to the vehicle, driver, and the operating conditions and environment, among others. The systems that control diesel vehicle emissions are particularly challenged at extremes of the operating environment due to the number of different systems required and their complexity. Because emissions from diesel vehicles are often higher under extreme conditions such as high/low temperature and high engine load, "average" emissions from on-road testing are strongly dependent on the proportion of the testing conducted under different driving conditions.

Even during highly regulated and prescriptive dynamometer testing, the levels of emissions generated by a vehicle vary continuously and span a range that may include levels that, if held across an entire test cycle, could be both above or below the regulated limits; pass/fail criteria are averages of the emissions generated during an entire test cycle on a gram per mile basis, not a cap on instantaneous emissions levels. In other words, regulated emissions standards represent thresholds that must be achieved *on average* over the entire test cycle. None of the emissions standards applicable to light-duty vehicles specifies a "shall not exceed" or absolute maximum emissions level for any given moment or segment of the test cycle, nor do the regulations specify thresholds for a given segment of a test cycle.

Mr. Smithers' opinions are primarily based on emissions results he obtained from testing a single Subject Vehicle (the Diesel Test Vehicle) using a portable emissions measurement system (PEMS). But non-standardized on-road measurements obtained from PEMS equipment are not predictive of on-cycle highly regulated and prescriptive standardized dynamometer test measurements. Notably, the EPA requirements for Tier 2 do not include emissions standards or testing procedures or requirements to evaluate light-duty vehicles emissions using PEMS equipment and the only method used by the EPA to establish emissions standards is laboratory dynamometer testing.

On-road emissions measurements cannot be directly compared to certification limits as there are many reasons why emissions during on-road PEMS testing can differ from, and be higher

than, emissions measured during certification dynamometer testing, including added weight and different operating conditions.

The dynamic operating conditions of on-road testing introduce a high degree of variability, and the PEMS equipment itself introduces additional measurement uncertainty. To account for the variability inherent with PEMS on-road testing and PEMS measurement uncertainty, two forms of adjustments are used: emissions multipliers to adjust the emissions measurements and "conformity factors" to adjust the emissions limit. Mr. Smithers ignored these adjustments and directly compared on-road PEMS testing results to certification dynamometer testing limits.

Mr. Smithers also evaluated the emissions results he obtained from on-road PEMS testing of a Cruze gasoline test vehicle (the Gasoline Test Vehicle) compared to emissions results he obtained through on-road PEMS testing of the Diesel Test Vehicle. Such evaluations are apples-to-oranges and misleading for a variety of reasons including:

- Diesel engines operate using inherently different engine technology platforms and after-treatment systems than gasoline engines, and as a result their emissions profiles, including NO_x, and their fuel economy performance are correspondingly different;
- The Cruze diesel vehicle was certified to the Tier2 Bin5 emissions standard, with a NO_x limit of 0.07 grams per mile (g/mi) for the FTP-75 certification test, while the Cruze gasoline was certified to the Tier2 Bin4 standard, with a NO_x limit of 0.04 g/mi. These vehicles are neither designed nor expected to have similar emissions levels; and
- Mr. Smithers focused his attention on NO_x emissions and disregarded important context provided by other regulated emissions, such as NMOG and CO.

Mr. Smithers' PEMS testing methodology is inconsistent with good engineering practices and yields unreliable and biased results. Among other things, Mr. Smithers failed to:

- Consider and account for (i) operating conditions that are outside of the dynamometer testing cycles he chose to use for comparisons (i.e., city and highway cycles), (ii) variability inherent with PEMS testing, and (iii) PEMS equipment measurement uncertainty;
- Test multiple vehicles of each type under the same operating conditions (e.g., ambient temperatures, wind, solar load, vehicle acceleration and speed, road grade, etc.) and same driving routes;
- Compare two diesel vehicles certified to the same tier and bin, which would be subject to the same underlying technical challenges and, therefore, could be used to identify potentially abnormal emissions vs. increases in emissions that are expected in diesel vehicle operation as a response to changing conditions;
- If a comparison to a gasoline vehicle is made, include a comparison of other emissions (e.g., CO, NMOG, and GHGs) that are typically more challenging for

gasoline vehicles, and not just NO_x emissions that are more challenging for diesel vehicles; and

- Document and retain complete records and log sheets, related testing protocols, vehicle and test conditions for each test (e.g., air conditioner use, diagnostic trouble code (DTC) status, wind conditions, etc.), vehicle maintenance, and vehicle storage procedures.

Instead, Mr. Smithers conducted over 8,000 miles of PEMS testing on a single Diesel Test Vehicle. While testing a single vehicle can yield information about that *specific vehicle's* performance, without additional information, the performance of that vehicle cannot be assumed to represent the performance of all vehicles of the same make, model, and/or model year. The operating condition of a vehicle is critically important to the emissions performance of that vehicle, and the results of one vehicle may not be representative of an entire population of a vehicle model, especially if the vehicle tested is not in proper working order.

The Diesel Test Vehicle used by Mr. Smithers demonstrated multiple characteristics and issues that compromise the reliability of his testing and the representativeness of that single Diesel Test Vehicle with respect to the Subject Vehicles generally. For example, during the February 28, 2020 multiparty inspection, multiple maintenance and repair issues were identified with the Diesel Test Vehicle, including an illuminated check engine light, multiple fault codes stored in the vehicle's computer system, an exhaust leak at one of the NO_x sensors, an unaddressed recall that included the replacement of a NO_x sensor and a software update, and cleared Diagnostic Trouble Codes. Additionally, when the Diesel Test Vehicle was tested on a dynamometer, its NO_x emissions on the FTP-75 cycle were over the certification limit, which could be indicative of vehicle-specific operation and/or maintenance issues with the Diesel Test Vehicle. Based on the unreliable nature of data collected from one vehicle with documented maintenance issues; the Diesel Test Vehicle's non-compliance with certification emissions limits; and the Diesel Test Vehicle's poorly documented maintenance, repair, and operating condition history, the conclusions that Mr. Smithers draws are not replicable and not sound.

In addition, there are several problems with the way in which Mr. Smithers collected, reviewed, analyzed, and interpreted the PEMS data from the Diesel Test Vehicle. While Mr. Smithers claims to have controlled and monitored his PEMS testing routes for variations in test conditions, there are many important and influential variations in his test conditions that he failed to adequately address in his test planning and data analysis. The main limitations with his approach include an overrepresentation of extreme temperature conditions (both high and low) that can increase emissions, a road grade analysis that did not account for rolling hills, and a biased data segmentation methodology. Both the Smithers and Levchenko Reports suggest that GM failed to disclose to the EPA key features of the emissions controls on the Subject Vehicles. These are unreliable, unsupported, and appear to reflect a lack of understanding of the certification disclosures and the relevant regulatory processes. Specifically, auxiliary emissions control devices (AECDs) that reduce the effectiveness of a vehicle's emissions system under certain conditions are allowed under – indeed, contemplated

by – applicable federal emissions regulations. Both Mr. Smithers and Dr. Levchenko speculated that all incidences of higher-than-average NO_x were the result of defeat devices with "cycle beating" mechanisms. Mr. Smithers and Dr. Levchenko did not appropriately consider (and in some cases ignored) valid engineering reasons for the disclosed AECDs. [redacted]

- In addition, there are several problems with the way in which Mr. Smithers collected, reviewed, analyzed, and interpreted the PEMS data from the Diesel Test Vehicle. While Mr. Smithers claims to have controlled and monitored his PEMS testing routes for variations in test conditions, there are many important and influential variations in his test conditions that he failed to adequately address in his test planning and data analysis. The main limitations with his approach include an overrepresentation of extreme temperature conditions (both high and low) that can increase emissions, a road grade analysis [redacted] and a biased data segmentation methodology. [redacted]

In short, based upon my review of the materials available to me and my engineering experience, my analysis has not identified any evidence of a defeat device or cycle detection behavior in the Subject Vehicles.

4.2 Summary of Opinions

Based on my review of materials, my education and training in mechanical engineering, my automotive industry and regulatory experience, and my work and analysis performed in this case, I have reached the following conclusions and hold each of the following opinions to a reasonable degree of engineering and scientific certainty:

1. Regulated emissions from light-duty vehicles are measured using standardized dynamometer testing procedures under closely controlled conditions, not through on-road emissions measurements. Test pass/fail criteria are averages of the emissions generated during a test on a gram per mile basis, not a cap on instantaneous emissions levels.

2. Similar to fuel economy, vehicle emissions, including NO_x, are variable and depend on many factors related to the vehicle, driver, and environment, among others, and are particularly sensitive to extreme operating environments.
3. Mr. Smithers' comparison of on-road PEMS measurements to federal certification standards is invalid because, among other things, on-road measurements obtained from PEMS are not directly comparable to highly regulated and prescriptive standardized dynamometer test measurements, Mr. Smithers oversampled extreme temperature conditions (low and high), and Mr. Smithers' data segmentation is flawed.
4. Extrapolating the results from PEMS testing conducted on *a single vehicle* to an entire population of vehicles is invalid and inconsistent with sound engineering judgment and practice. This is especially true where the one vehicle tested had a number of problems, including: a poorly documented NO_x sensor replacement, abnormally high NO_x results when tested on standardized dynamometer test cycles, and uncertainty regarding the presence of DTC codes, the impact of a significant leak in the emissions after-treatment system, air conditioner use during testing, and vehicle maintenance.
5. Mr. Smithers' comparisons between the Diesel Test Vehicle and the Gasoline Test Vehicle is an apples-to-orange comparison that renders any conclusions invalid.
6. Auxiliary Emissions Control Devices (AECDs) are a typical aspect of v[redacted]
7. [redacted]
8. [redacted]
9. [redacted]

5 OVERVIEW OF THE MODEL YEAR 2014/2015 CHEVROLET CRUZE DIESEL

The Chevrolet[8] Cruze Diesel ("Cruze Diesel") is a compact sedan that was sold in the United States (U.S.) for the 2014 and 2015 model years (MY) with essentially unchanged specifications.[9] This section provides a summary of the Cruze Diesel technical specifications as they pertain to the engine and after-treatment control systems, and an overview of the emissions testing that was conducted on the Cruze Diesel platform by GM during the emissions certification process and other analyses conducted by GM.

5.1 Engine History and Emissions Control Systems on the Cruze Diesel

The Cruze Diesel is a four-door, five-passenger front-wheel drive vehicle with a curb weight of 3,475 pounds and an overall length of 181.0 inches.[10] The vehicle uses a 2.0L turbo diesel engine based on GM's "Family B" engine architecture,[11] which is rated for an SAE-certified 151 horsepower with 264 pound feet (lb-ft) of torque when paired with an Aisin AF40 6-speed automatic transmission.[12] It also has an "overboost" feature that is capable of increasing torque to 280 lb-ft for periods of about 10 seconds.[13] Based on the EPA fuel economy rating for this vehicle at the time of sale, the Cruze Diesel was rated for an estimated fuel economy of 27/46/33 city/highway/combined miles per gallon.[14] As a result of changes to the calculations used to determine EPA fuel economy label values, which were first implemented for MY2017 vehicles,[15] the Cruze Diesel is rated by the EPA for an estimated 27/44/32 city/highway/combined miles per gallon using the EPA's updated

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8 Chevrolet is a division of General Motors.

9 "2015 Chevrolet Cruze Specifications," *General Motors*, available at https://media.gm.com/media/us/en/chevrolet/vehicles/cruze/2015.tab1.html. Accessed on June 5, 2020; "2014 Chevrolet Cruze Specifications," *General Motors*, available at: https://media.gm.com/media/us/en/chevrolet/vehicles/cruze/2014.tab1.html. Accessed on Jun. 5, 2020.

10 *Id.*

11 GM Powertrain USA Information Guide Model Year 2014, October 2013; GM Powertrain USA Information Guide Model Year 2015, December 2014.

12 "2015 Chevrolet Cruze Specifications," *General Motors*, available at https://media.gm.com/media/us/en/chevrolet/vehicles/cruze/2015.tab1.html. Accessed on June 5, 2020; "2014 Chevrolet Cruze Specifications," *General Motors*, available at: https://media.gm.com/media/us/en/chevrolet/vehicles/cruze/2014.tab1.html. Accessed on June 5, 2020.

13 *Id.*

14 "Fuel Economy, 2015 Chevrolet Cruze Diesel," *Environmental Protection Agency*, available at https://www fueleconomy.gov/feg/comparempg.shtml#id=35732. Accessed on June 5, 2020; "Fuel Economy, 2014 Chevrolet Cruze Diesel," *Environmental Protection Agency,* available at https://www fueleconomy.gov/feg/comparempg.shtml?words=#id=33578. Accessed on June 5, 2020.

15 "Updates to Fuel Economy Test Methods and Calculations," Environmental Protection Agency, June 22, 2015, available at https://www.epa.gov/fueleconomy/basic-information-fuel-economy-labeling. Accessed on June 5, 2020.

calculations.[16] The MY2014 and MY2015 Cruze Diesel share the same specifications. Mr. Smithers used a single, used, MY2015 Cruze Diesel for his tests.[17]

5.1.1 Emissions Control Systems

The Cruze Diesel is equipped with an emissions control system calibrated to control tailpipe exhaust emissions during operation allowing the Cruze Diesel to meet the applicable emissions standards.[18] Tailpipe emissions are controlled by adjusting the combustion process in the engine first and then employing different after-treatment strategies to mitigate the emissions that will ultimately be emitted out of the tailpipe.

The combustion process is affected by several factors, including quantity of fuel injected, fuel pressure, number of injections, timing of injections and more. NO_x emissions in particular are also reduced through the incorporation of an exhaust gas recirculation (EGR) system,[19] which recycles a portion of exhaust gas back through the engine to reduce the combustion temperature altering the emissions profile and resulting in a decrease of engine-out NO_x production.[20]

The Cruze Diesel also includes three main after-treatment components: a Diesel Oxidation Catalyst (DOC), which converts carbon monoxide (CO) and hydrocarbons to carbon dioxide (CO_2) and water; a Diesel Particulate Filter (DPF), which filters/traps particulate matter from the exhaust; and a Selective Catalytic Reduction (SCR) system that uses diesel exhaust fluid (DEF) and a specially coated catalytic converter to reduce the amount of NO_x emissions.[21,22]

The DPF filter accumulates particulate matter during operation and is periodically regenerated through a process that elevates the exhaust gas temperature above typical temperatures during operation in order to burn away particulates that have been trapped on the filter, thereby "cleaning" the filter.[23] The onboard computer determines when a

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16 "Fuel Economy, 2015 Chevrolet Cruze Diesel," *Environmental Protection Agency*, available at https://www fueleconomy.gov/feg/comparempg.shtml#id=35732. Accessed on June 5, 2020; "Fuel Economy, 2014 Chevrolet Cruze Diesel," *Environmental Protection Agency,* available at https://www fueleconomy.gov/feg/comparempg.shtml?words=#id=33578. Accessed on June 5, 2020.

17 *See* Smithers Report, ¶ 68.

18 GMCOUNTS000812193.

19 Deposition of James Perrin, July 19, 2019 (hereafter "Perrin Deposition"), 64:24-65:24.

20 "Combustion in the diesel engine" Bauer, H. (Ed.). (1999). Diesel-engine management (Vol. 2). Society of Automotive Engineers.

21 "Getting to Know Your 2014 Cruze Clean Turbo Diesel," *General Motors*, p. 18, available at https://my.chevrolet.com/content/dam/gmownercenter/gmna/dynamic/manuals/2014/chevrolet/cruze/GTK_2014_Cruze%20Diesel_23145971_A.pdf. Accessed on June 5, 2020.

22 GMCOUNTS000448249.

23 GMCOUNTS000364835 at GMCOUNTS000364861, GMCOUNTS000365051.

regeneration process is necessary based on a number of factors. This process can occur "passively" during normal vehicle operation, or, in some cases, an "active" regeneration is required and the vehicle may need to be operated continuously for approximately 25 minutes at speeds greater than 30 mph for the regeneration exhaust temperatures to be maintained.[24,25]

The DPF regeneration process typically increases fuel consumption[26] during the regeneration period and may also increase other vehicle emissions.[27] When extended driving is needed to clear the DPF, the Cruze Diesel driver information center will display "DIESEL PARTIC FILTER IS FULL CONTINUE DRIVING" or "DIESEL PARTIC FILTER IS FULL CONTINUED DRIVING MANDATORY."[28] If the DPF becomes plugged with particulates, a "service engine soon" light will become illuminated on the instrument cluster and dealer servicing will be necessary.[29]

The SCR system reduces NO_x emissions using an additive fluid called DEF, which is a solution of urea[30] that is sprayed into the exhaust of a diesel vehicle, becomes stored on the interior surfaces of the SCR catalytic converter, and reacts (with assistance of the catalyst) with NO_x in the exhaust, resulting in a chemical reaction that breaks down NO_x emissions into nitrogen gas and water.[31] In the Cruze Diesel, the DEF solution is stored under the load floor carpet in the trunk[32] in a tank with a capacity of 18.5 L (4.9 gallons).[33] DEF is consumed during vehicle operation and requires regular replenishment.[34] The DEF tank on the Cruze Diesel is expected to last for several thousand miles, depending on vehicle usage and environmental conditions.[35] Prior to July 2014, the EPA evaluated the refill interval of DEF for light-duty vehicles (such as the Cruze Diesel) on a case-by-case basis, but starting in

24 GMCOUNTS000364835 at GMCOUNTS000364862.

25 GMCOUNTS000364835 at GMCOUNTS000364861, GMCOUNTS000365051.

26 GMCOUNTS000364835 at GMCOUNTS000365051.

27 Rebecca Darr Deposition, June 18, 2019 (hereafter "Darr Deposition"), 222:11-223:4.

28 GMCOUNTS000364835 at GMCOUNTS000364967.

29 GMCOUNTS000364835 at GMCOUNTS000364862, GMCOUNTS000365052.

30 Urea is the "active" ingredient in DEF, but is not used directly in the SCR's mitigation of NO_x. The urea in DEF is first converted to ammonia, which participates in the chemical reactions that mitigate NO_x in the SCR.

31 GMCOUNTS000364835 at GMCOUNTS000365086.

32 GMCOUNTS000364835 at GMCOUNTS000365086.

33 GMCOUNTS000364835 at GMCOUNTS000365052.

34 GMCOUNTS000364835 at GMCOUNTS000365053.

35 GMCOUNTS000364835 at GMCOUNTS000365052 - GMCOUNTS000365053, GMCOUNTS000364967.

July 2014, the EPA set a minimum refill interval of 4,000 miles.[36] During development, GM targeted a DEF refill interval for the Cruze Diesel that was equal to the oil change/maintenance interval.[37] The production version of the Cruze Diesel has an oil change/maintenance interval of 7,500 miles and thus the DEF refill interval is approximately the same.[38]

The Cruze Diesel should be filled with DEF that bears the API certified or ISO 22241 labels.[39] As the DEF is consumed, the Driver Information Console will give warnings notifying the driver of the approximate fluid range remaining, starting when there is an approximate range of 1,000 miles remaining.[40] At this time, the DEF is approximately "11 L (3 gal) low," indicating that approximately 7.5 L or 1.9 gallons remain.[41] If the DEF tank is depleted, the maximum speed of the vehicle is progressively limited depending on the number of miles driven with the tank empty. This progression starts with a speed limit of 65 mph after 350 miles are driven without DEF, followed by a limit of 55 mph after an additional 75 miles are driven, and finally a limit of 4 mph after an additional 75 miles are driven.[42] I also note that the Owner's Manual indicates the emission control hardware on the vehicle is designed exclusively for Ultra-Low Sulfur Diesel Fuel (ULSD),[43] although 20% biodiesel may be used.[44]

The engine and after-treatment operation are controlled-by an Electronic Diesel Control (EDC) unit (specifically the Bosch EDC17), which is an on-board computer that works to optimize the engine and after-treatment behavior by monitoring environmental conditions, driver's demands, and engine and after-treatment conditions.[45] In this section I discuss the main aspects of the after-treatment system that are apparent to the vehicle operator (i.e., the DPF regeneration process and the SCR refilling); Appendix D provides a more in-depth review of engine management and after-treatment systems.

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36 "EPA Sets Standards for Diesel Fluid Systems; Adopts Relief Measures for Nonroad Equipment," *Environmental Protection Agency*, July 2014, available at https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100JWJ1.txt. Accessed on June 5, 2020.

37 Deposition of Robert Sutschek, August 8, 2019 (hereafter "Sutschek Deposition"), 67:4-11.

38 GMCOUNTS000364835 at GMCOUNTS000365198.

39 GMCOUNTS000364835 at GMCOUNTS000365053.

40 GMCOUNTS000364835 at GMCOUNTS000365053.

41 GMCOUNTS000364835 at GMCOUNTS000364967.

42 GMCOUNTS000364835 at GMCOUNTS000365054.

43 GMCOUNTS000364835 at GMCOUNTS000364862.

44 GMCOUNTS000364835 at GMCOUNTS000365079.

45 GMCOUNTS000448249

5.2 GM's Emissions Testing of the Cruze Diesel

5.2.1 Emissions Certification Dynamometer and In-Use Testing

The MY2014 and MY2015 Cruze Diesel vehicles were tested for emissions according to the Federal EPA Tier2 Bin5 standards[46] which include specific limits for emissions such as non-methane organic gases (NMOG), carbon monoxide (CO), nitrogen oxides (NO_x) and particulate matter (PM). The vehicle's emissions are assessed using a number of standardized dynamometer[47] testing cycles, conducted under rigorously controlled conditions. Different emissions limits apply to different test cycles, with higher limits for more demanding test cycles. Mr. Smithers focuses on the FTP-75 and HWFET standards for NO_x emissions, which are set at 0.07 g/mi and 0.09 g/mi, respectively, for vehicles certified to Tier2 Bin5. None of the emissions standards for dynamometer testing are appropriate for use as PEMS testing limits,[48] as discussed in detail in Section 6.2 below. I provide a more comprehensive review of the dynamometer test cycles and in-use testing in Appendix E.

Five driving schedules are used for the dynamometer testing that supports vehicle certification according to EPA Tier2 Bin5:

Federal Test Procedure 75 Driving Schedule (FTP-75);

Highway Fuel Economy Test Driving Schedule (HWFET);

Supplemental FTP Driving Schedule (SFTP US06 or US06);

Speed Correction Driving Schedule (SFTP SC03 or SC03); and

Cold temperature FTP-75 performed at a lab temperature of 20 °F.

Each driving schedule is intended to replicate a specific driving condition in terms of speed profile, driver's aggressiveness, and ambient conditions. The driving schedules do not include grade changes (i.e., driving uphill or downhill) and, except for the SC03, are driven with the air conditioner off. Emissions limits are specified for each driving schedule (or

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46 GMCOUNTS000095218. GMCOUNTS000812193. As I discuss in Appendix E, California has its own emissions standards and the Cruze was certified to both standards. Due to the stricter limit on NO_x in the federal EPA Tier2 Bin5 standard (0.07 g/mi NO_x) compared to California's LEV160 standard (0.16 g/mi NMOG + NO_x), my report focuses on the EPA standards.

47 A dynamometer (also referred to as "chassis dynamometer") is a test apparatus used for testing vehicles in a laboratory settings. Conceptually, a dynamometer functions similarly to a treadmill or a spinning bicycle in the sense that it uses a roller assembly to simulate road loads in a controlled, indoor environment without actually moving the vehicle.

48 According to a 2014 study, "[i]t is unrealistic to expect that a vehicle certified to a certain emission standard will stay below the certified limits under all driving conditions" and "high on-road NO_x emissions compared to test standards were observed and attributed to "transient increases in engine load that constitute real-world driving (e.g., uphill driving, acceleration on a ramp, or positive accelerations from a standstill), or to regeneration events that are part of the normal operation of diesel exhaust aftertreatment systems." *See* "Real-World Exhaust Emissions from Modern Diesel Cars" International Council on Clean Transportation, 2014, p. 17 and p. ii.

combination of driving schedules) because emissions depend on the characteristics of the test cycle. The SFTP emissions standard combines the FTP emission standard with the US06 and SC03 test procedures, through a weighted average of 35%, 28%, and 37%, respectively, for the three test cycles.

The Subject Vehicles were certified after demonstrating compliance with the Tier2 Bin5 emissions standards for both the MY2014 and MY2015 vehicles. A summary of emissions limits and the certification test results data for the MY2014 Cruze Diesel is shown in Figure 5-1 below.

[redacted]

As discussed further in Appendix E, in addition to certification testing, the EPA requires in-use testing of vehicles that have been in customer service for some period to ensure on-going compliance with applicable emissions standards.[50] This testing is conducted on the dynamometer following the protocol utilized during the original certification.

[redacted]

49 [redacted]

50 "Overview of Certification and Compliance for Vehicles and Engines," *Environmental Protection Agency*, available at https://www.epa.gov/ve-certification/overview-certification-and-compliance-vehicles-and-engines. Accessed on June 5, 2020.

51 [redacted]

HIGHLY CONFIDENTIAL

[redacted]

52 [redacted]

53

54

55 Code of Federal Regulations, Part 600, Section 113-12(i)(2).

56 CREE = (3.172 × HC) + (1.571 × CO) + CO_2. *See* Code of Federal Regulations, Part 600, Section 113-12(i)(2).

57 [redacted]

[redacted]

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58 [redacted]

59 [redacted]

60 [redacted]

61 [redacted]

62 [redacted]

63 [redacted]

64 [redacted]

65 [redacted]

66 [redacted]

[redacted]

5.2.2 Disclosures Related to Certification

Any component of a vehicle affecting its emissions, including, but not limited to, after-treatment devices, engine control units, sensors, and actuators, fall under the EPA's definition of an emission control system.[73] Selective operation of after-treatment and other emissions control system components is necessary for a variety of reasons. The control strategies that enable, disable, and modify emissions control system elements are called auxiliary emission control devices (AECDs), which are discussed in more detail in Appendix E. Multiple AECDs are typically implemented in each vehicle's emissions control system to control emissions and vehicle operating parameters under different conditions. It is well known by the EPA, CARB, and the automotive industry that engine and after-treatment systems do not operate the same in all conditions and are practically challenged under certain conditions.

During vehicle certification with the EPA, engine and automobile manufacturers are required to provide a list of all AECDs that includes an explanation of the function and justification for each.[74] I describe GM's AECD disclosures to the EPA in Section 7.1.

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67 [redacted].

68 [redacted]

69 [redacted].

70 [redacted].

71 [redacted].

72 GMCOUNTS000852421 at GMCOUNTS000852422.

73 Code of Federal Regulations, Part 86, Section 1803-01 ("*Emission control system* is a unique group of emission control devices, auxiliary emission control devices, engine modifications and strategies, and other elements of design designated by the Administrator used to control exhaust emissions of a vehicle.").

74 I describe this process in Appendix E.

5.2.3 [redacted]

5.2.4 [redacted]

[redacted]

[redacted]

5.2.4.1 [redacted]

[redacted]

81 [redacted]
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[redacted]

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87 [redacted]

88 [redacted]

89 [redacted]

90 [redacted]

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92 [redacted]

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93 [redacted]

94 [redacted]

5.2.4.2 [redacted]

5.2.4.3 [redacted]

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95 [redacted]

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5.2.4.3.1 [redacted]

5.2.4.3.2 [redacted]

[redacted]

102 [redacted]

103 [redacted]

104 [redacted]

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106 [redacted]

107 [redacted]

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[redacted]

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116 [redacted]

117 [redacted]

118 [redacted]

119 [redacted]

120 [redacted]

[redacted]

5.2.4.3.3 [redacted]

[redacted]

121 [redacted]

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[redacted]

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127 [redacted]

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5.2.5 [redacted]

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131 [redacted]
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6 PLAINTIFFS' EXPERTS' REPORTS ARE BASED ON AN UNRELIABLE METHODOLOGY AND SCIENTIFICALLY INCORRECT ASSUMPTIONS

Plaintiffs have submitted technical reports written by two experts: Mr. Smithers and Dr. Levchenko. Mr. Smithers conducted off-cycle on-road measurements of NO_x (and other) emissions using a PEMS unit on one MY2015 Cruze diesel vehicle ("Diesel Test Vehicle") and one MY2015 Cruze gasoline vehicle ("Gasoline Test Vehicle"). Dr. Levchenko analyzed the Subject Vehicles' software code and calibration with respect to the operation of selected AECDs. In this section, I discuss the limitations and inaccuracies of these reports and I present my analysis of Mr. Smithers' PEMS testing data.

Mr. Smithers' testing is fundamentally flawed and is incompatible with well-established engineering principles due to, among other things, insufficient and unreliable test procedures, execution, documentation, and data analysis. Mr. Smithers overlooked several well-understood reasons for the emissions observed during his on-road testing, including vehicle-to-vehicle variability, test conditions, and inherent variability with PEMS testing. The sections below will evaluate these main issues of Mr. Smithers' testing.

6.1 Mr. Smithers' Comparison of Diesel and Gasoline NOx Emissions is Inappropriate and Meaningless

In his report, Mr. Smithers compared the NO_x emissions results from one Gasoline Test Vehicle to the NO_x emissions results from one Diesel Test Vehicle. For example, Mr. Smithers' Report describes Figure 9-3 as showing "[t]he NO_x emissions from the diesel Cruze [as] compared to the average gasoline Cruze NO_x emissions…for city driving conditions," through which Mr. Smithers finds that *"[t]he diesel Cruze only spends 0.5% of VMT [vehicle miles traveled] with emissions below the gasoline Cruze, with 99.5% of the VMT above the emissions of the gasoline Cruze. Cruze diesel emissions are 5 times the gasoline emissions 79.1% of the VMT, 10 times the gasoline emissions 53.3% of the VMT, and 30 times the gasoline emissions 12.3% of the VMT."*[134] However, such comparisons are inappropriate and meaningless for a variety of reasons, including, but not limited to, the three main reasons I discuss below.

6.1.1 Diesel Engines Operate Differently than Gasoline Engines

First, Mr. Smithers failed to acknowledge that diesel engines operate using different fuel and inherently different engine technology platforms and after-treatment systems than gasoline engines. As a result, their emissions profiles, including NO_x and greenhouse gases (GHGs), and their fuel economies are correspondingly different. More specifically, while gasoline engines require a spark from a spark plug to ignite fuel within the cylinders, diesel vehicles utilize a high level of compression to ignite the fuel. These different ignition strategies require different fuel characteristics, different ratios of air to fuel in the engine cylinders, different compression ratios of the air-fuel mixtures, and other differences in engine

134 Smithers Report, ¶ 107.

hardware and operating parameters. In addition, the after-treatment technologies used to mitigate vehicle-out emissions from diesel and gasoline engines are distinct. The three-way catalyst used for exhaust after-treatment on gasoline vehicles is both effective and relatively insensitive to vehicle operating conditions once the efficient operating temperature is reached.[135] The after-treatment systems used on diesel vehicles are more complex, requiring multiple after-treatment steps (for example, the use of diesel oxidation catalyst (DOC), diesel particulate filter (DPF), and selective catalyst reduction (SCR), as described further in Appendix D) to control emissions. Further, the effectiveness of these after-treatment devices in diesel vehicles can be impacted by changes in vehicle operating conditions (vehicle acceleration and speed, engine load, fuel quality, ambient temperature and more) and some of the after-treatment components require periodic regeneration.

As a result of the use of these different technologies, a gasoline engine and a diesel engine *will be expected* to produce different levels of different emissions. While gasoline engines typically produce higher amounts of carbon monoxide (CO) and non-methane organic gases (NMOG), diesel engines typically produce less of these emissions but more particulate matter (PM) and NO_x.[136, 137, 138] In addition, the fuel economy of diesel vehicles is typically higher than that of otherwise-comparable gasoline vehicles because compression ignition engines used by diesel vehicles tend to be more efficient.[139] Mr. Smithers' comparisons inherently assume that the response of NO_x emissions to changes in vehicle operating conditions should be similar between a diesel and gasoline vehicle. This is simply not the case, as acknowledged by the EPA and the International Council on Clean Transportation (ICCT), and as generally well known by engineers.[140] Finally, Mr. Smithers did not drive the Diesel and Gasoline Test Vehicles under the same conditions and did not analyze the resulting data using the same approach. In a later section I will show that the Gasoline Test Vehicle was not tested at temperatures above 95 °F, which is where for some segments, the Diesel Test Vehicle had higher emissions, and that the mileage distribution for the Gasoline Test Vehicle was different when compared to the Diesel Test Vehicle. Therefore, the PEMS

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135 "Vehicle NOx Emissions: The basics." *IICCT*. Available at: https://theicct.org/cards/stack/vehicle-nox-emissions-basics#1 - https://theicct.org/cards/stack/vehicle-nox-emissions-basics#6. Accessed on June 5, 2020.

136 İ. A. Reşitoğlu et al., "The pollutant emissions from diesel-engine vehicles and exhaust aftertreatment systems." *Clean Technologies and Environmental Policy*, Volume 17, pp. 15–27, 2015.

137 R. Hammerle et al., "Emissions from Current Diesel Vehicles," SAE Technical Paper 942043, 1994.

138 "Diesel Vehicles." *Environmental Protection Agency*. Available at: https://www fueleconomy.gov/feg/di_diesels.shtml. Accessed on June 5, 2020.

139 *Id.*

140 "Vehicle NOx Emissions: The basics." *IICCT*. Available at: https://theicct.org/cards/stack/vehicle-nox-emissions-basics#1 - https://theicct.org/cards/stack/vehicle-nox-emissions-basics#6. Accessed on June 5, 2020.

data collected by Mr. Smithers for the Gasoline and Diesel Test Vehicles cannot be used to directly compare these two vehicles.

6.1.2 The Cruze Gasoline and Cruze Diesel Vehicles were Certified to Different Emissions Standards

Second, Mr. Smithers' comparisons of the NO_x emissions of the Gasoline Test Vehicle to the Diesel Test Vehicle were further inappropriate because these vehicles were certified to different emissions standards.[141] The Cruze diesel was certified to the Tier2 Bin5 standard, with a NO_x limit of 0.07 grams per mile (g/mi) for the FTP-75 test cycle,[142] while the Cruze gasoline was certified to the Tier2 Bin4 standard, with a NO_x limit of 0.04 g/mi for that same cycle.[143] Apples-to-oranges comparisons like those made by Mr. Smithers of the NO_x emissions of the Gasoline Test Vehicle to the Diesel Test Vehicle have little to no value.

As an illustrative comparison of the implications of differing emissions certifications, Figure 6-1 below presents the EPA's published Smog Rating (based on emissions certification data), which allows consumers to see how a vehicle's emissions compare with another vehicle's emissions.[144] The left panel of the figure shows that the MY2015 Subject Vehicles had a Smog Rating of "6" (10 being the "best") and earned the EPA's SmartWay designation,[145] which alerts consumers to the most environmentally friendly vehicles, generally in the top 20% of the cleanest and most efficient vehicles. In contrast, the right panel of the figure shows that the MY2015 Subject Vehicles had a lower Smog Rating of "5" and did not earn the EPA's SmartWay designation that was achieved by the MY2015 Cruze gasoline vehicle.

The Cruze gasoline was equipped with a "downsized"[146] 1.4 L gasoline turbo engine (as compared with the Subject Vehicles' 2.0L engine) that achieved good fuel economy and emissions for a gasoline vehicle. GM certified the Cruze gasoline to a more stringent "bin" level (i.e. to lower emissions limits) and Mr. Smithers' use of it as a comparison with the Subject Vehicles was therefore biased.

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141 See Appendix E for a further discussion of emissions standards.

142 "United States Environmental Protection Agency 2015 Model Year Certificate of Conformity with the Clean Air Act of 1990," *Environmental Protection Agency,* available at https://iaspub.epa.gov/otaqpub/display_file.jsp?docid=33641&flag=1.

143 Manufacturers can select from a "menu" of bins within the Tier level. Bins are chosen based on manufacturer certification and compliance strategy and the specific performance of the vehicle.

144 https://www fueleconomy.gov/feg/Find.do?action=sbs&id=35008&id=35732. Accessed on June 5, 2020

145 *See* https://www.epa.gov/greenvehicles/consider-smartway-vehicle. Accessed on June 5, 2020

146 "Downsize, boosted gasoline engines." *ICCT.* Available at: https://theicct.org/sites/default/files/publications/Downsized-boosted-gasoline-engines_working-paper_ICCT_27102016_1.pdf. Accessed on June 5, 2020

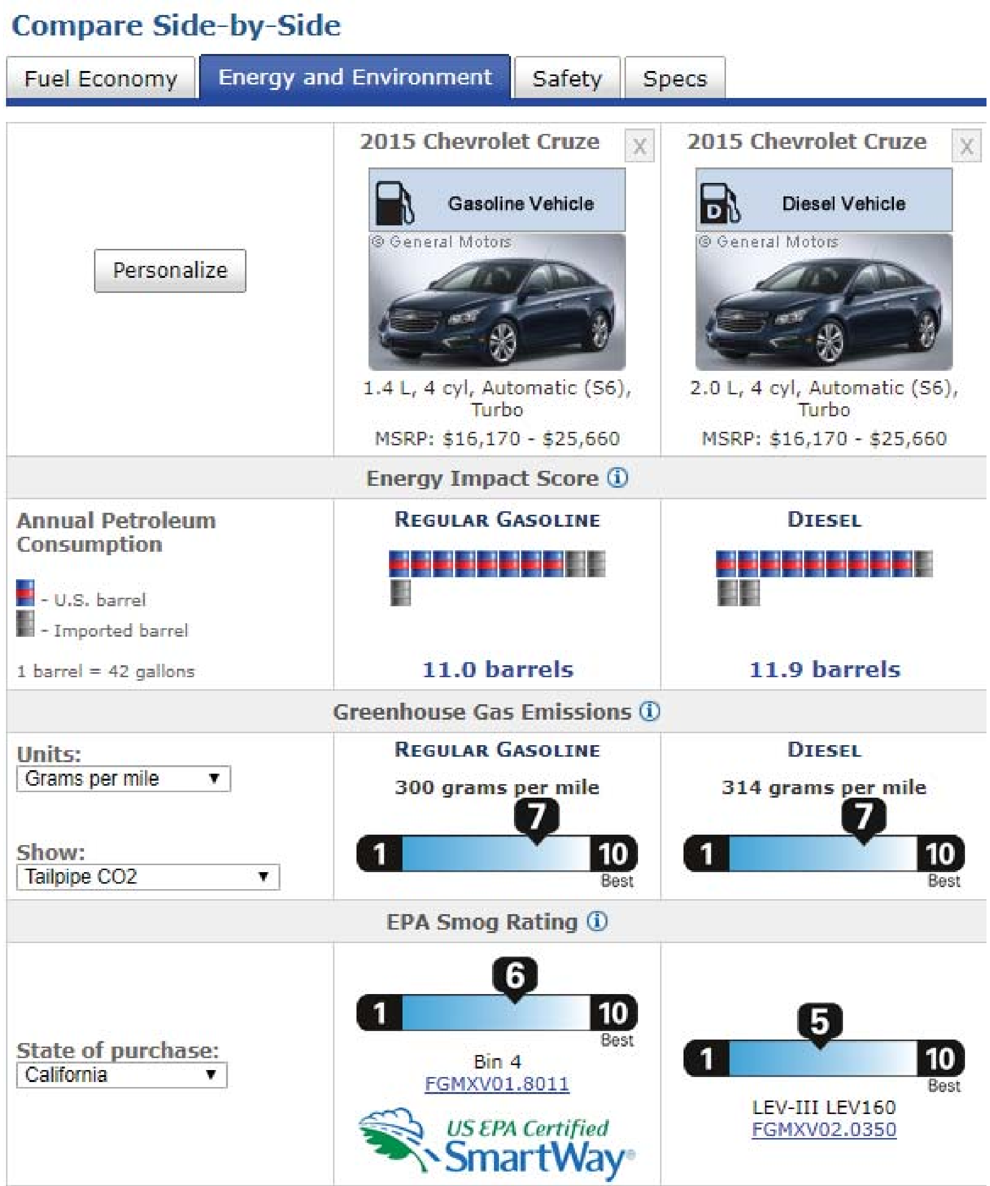

Figure 6-1 Smog Rating and SmartWay designation for the MY2015 Cruze gasoline and MY2015 Cruze diesel vehicles.[147]

6.1.3 Mr. Smithers Disregards Important Context of Other Emissions

Third, Mr. Smithers focused his attention on NO_x emissions and completely disregarded important context provided by other regulated emissions, such as NMOG and CO which are especially relevant to a gasoline vehicle's emissions compliance. It is therefore illogical to view specific emissions in a vacuum.

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147 https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=35008&id=35732. Accessed on June 5, 2020

NMOG and CO are important components of the regulatory scheme that cannot be ignored, especially when analyzing a gasoline vehicle's emission system. For example, the MY2015 Cruze gasoline vehicle had NMOG emissions that were more than 20 times higher than the Subject Vehicles' NMOG emissions during the SC03 and over 350 times the US06 certification test cycles and more than two times higher during the HWFET and FTP-75 test cycles.[148] Deviations are similarly high when considering CO emissions with the gasoline vehicle resulting in CO emissions ranging from over 8 times (on the FTP-75) to over 900 times (on the US06) higher than the Subject Vehicle. This means that the gasoline vehicle had thinner margins for NMOG and CO emissions when tested on-road.

As another example, the CO emissions of the Diesel Test Vehicle for all the segments driven during Mr. Smithers on-road testing were below the CO limit for Tier2 Bin5 (see Figure 6-2 CO emissions of the). Data show how the Diesel Test Vehicle CO emissions was not sensitive to testing variability since for every single segment driven by Mr. Smithers, the Diesel Test Vehicle remained below the Tier2 Bin5 CO limit.

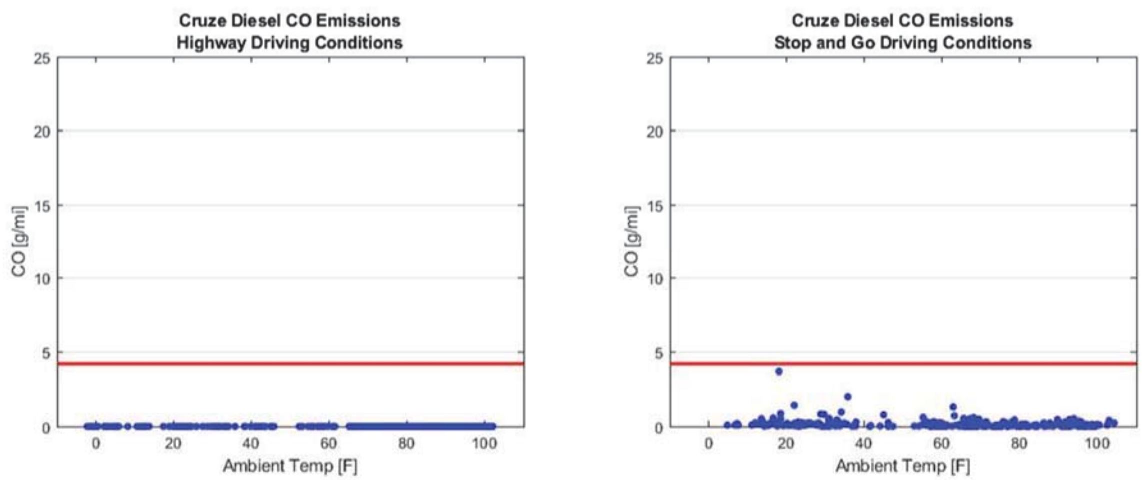

Figure 6-2 CO emissions of the Diesel Test Vehicle compared to the Tier 2 Bin 5 regulatory standard of 4.2 g/mi.

Furthermore, as described in detail in Appendix E, there are relevant engineering trade-offs that require OEMs to consider all types of emissions.

Rather than Mr. Smithers' flawed approach, a reasonable and robust engineering comparison between a diesel and gasoline vehicle would, at a minimum: (1) start with vehicles certified to same tier and bin; (2) test multiple of each type of vehicle under the same operating conditions (e.g., ambient temperatures, wind, solar load, vehicle speed, road grade) and same driving routes and (3) include a comparison of other emissions (e.g., CO, NMOG, PM, and

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148 *See* Certification Summary Information Report Cruze Diesel MY2015, October 17, 2014, available at https://iaspub.epa.gov/otaqpub/display_file.jsp?docid=33810&flag=1. Certification Summary Information Report Cruze Gasoline MY2015, November 17, 2014, available at https://iaspub.epa.gov/otaqpub/display_file.jsp?docid=33808&flag=1.

GHGs), including those types of emissions that are more challenging for gasoline vehicles, and not just NO_x emissions that are more challenging for diesel vehicles.

6.2 Mr. Smithers' Comparisons of On-Road NO_x Emissions from PEMS Testing to EPA Dynamometer Test Emissions Limits are Inappropriate

In his report, Mr. Smithers compared his PEMS testing results, by segment, to the EPA's "city" (Federal Test Procedure (FTP-75)) and "highway" (Highway Fuel Economy Test Procedure (HWFET)) limits for NO_x emissions, which are limits set for carefully controlled laboratory conditions.[149] Based on his observation that the Diesel Test Vehicle's on-road emissions were higher than the FTP and HWFET emissions standards, Mr. Smithers concluded that the NO_x emissions excursions were due exclusively to vehicle design parameters that control the engine and after-treatment system of the Subject Vehicles. In other words, Mr. Smithers opined that measured NO_x excursions during his on-road testing are evidence that the Subject Vehicles contain defeat devices.[150] Below, I explain why these comparisons are not correct in the first instance, as well as the variety of reasons why emissions during on-road during PEMS testing can be higher than emissions measured during certification dynamometer testing *without* the presence of any defeat devices.

6.2.1 PEMS Equipment is Known to Introduce Measurement Uncertainty

Critically, and in contrast to the approach taken by Mr. Smithers throughout his report, it is my opinion that it is inappropriate to directly compare emissions generated by on-road testing and recorded by PEMS testing equipment to EPA standards that apply to meticulously controlled laboratory test conditions captured by dynamometer testing equipment. EPA

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149 *See* Smithers Report, Figure 9-1 and ¶105 ("The 2015 Cruze diesel was tested over the course of 1,825 miles and 278 test segments in city driving conditions. […] The vehicle spends 82.6% of vehicle miles traveled above the emission standard of 70 mg/mile, with only 17.4% of VMT below the standard. The vehicle spends 59.7% of VMT over twice the standard, 29.2% of VMT over four times the standard, and 7.8% over ten times the standard."). *See also* Smithers Report, Figure 9-4 and ¶108 ("The Cruze diesel was tested over 6,236 miles and 403 test segments in steady highway driving conditions. […] The vehicle spends 47.3% of vehicle miles traveled above the emission standard of 70 mg/mile, with only 52.7% of VMT below the standard. The vehicle spends 32.3% of VMT over twice the standard, 19.5% of VMT over four times the standard, and 5.2% over ten times the standard."). See Appendix E for a discussion of EPA test cycle protocols.

150 *See* Smithers Report, Figure 9-7 and ¶112 ("As can be seen in Figure 9-7, emissions increase sharply at temperatures above 86°F, the upper-end temperature of the FTP-75 certification test. At temperatures as low as 91.9°F, emissions of NO_x can reach levels as high as 2,038 mg/mile, or 29 times the federal standard. Emissions also increase as ambient temperature decreases, where emissions increase to levels as high as 605 mg/mile at 7.6°F, or 8.6 times the federal standard." See also Smithers Report, ¶96 ("For this reason, while testing on a chassis dynamometer for defeat devices, it can never be ruled out that the vehicle has been configured to operate differently in a testing environment than in real world driving. Thus PEMS is important for detection and quantification of defeat and strategies designed to derate emissions outside of chassis dynamometer testing.") *See also* Smithers Report, ¶133 ("The high NO_x emissions measured and summarized in section 9 for the 2015 Cruze diesel are the result of the presence of emission derating strategies.")

regulations require that a certified vehicle's emissions control system does not unnecessarily behave differently on-road compared to dynamometer testing under comparable driving conditions.[151] However, this does not mean that emissions levels must be identical on-road and on-cycle. In light of well-known issues regarding the accuracy of PEMS equipment[152] and the inherent variability of on-road testing,[153] EPA has not set any compliance limits for emissions collected using PEMS devices for light-duty vehicles.

As explained further in Appendix E, PEMS represent a newer self-contained emission measurement method that can be used while a vehicle operates on the road, with resulting data often referred to as "on-road" or real driving emissions (RDE). By contrast, laboratory measurements are performed under repeatable and carefully controlled conditions such as road loads, test cycles speed profiles, ambient conditions, fuels, and many other factors that could affect emissions. As stated by the EPA, "[t]esting vehicles in controlled laboratory conditions establishes a level playing field for all cars and ensures that the test results are consistent, accurate, repeatable, and equitable among different vehicle models and manufacturers."[154]

PEMS can be used in the laboratory on a dynamometer and/or while the vehicle is driven on the road. Mr. Smithers stated that when properly set up, "the same test cycle driven on the road or on the chassis dynamometer should produce the same results."[155] In theory this may be partially correct, but in practice, it is extremely challenging to replicate the same set of laboratory test conditions on-road, and notably Mr. Smithers did not conduct any such comparison to assess the reliability of his testing equipment.

The measurement uncertainty associated with PEMS equipment represents one of the main limitations of on-road evaluations and is well documented. For example:

- A comparison of a SEMTECH-D PEMS unit against traditional dynamometer laboratory equipment using Constant Volume Sampling (CVS), used for emission certification testing, showed that the PEMS unit could have mass reading error up to 29% during a single FTP dynamometer run.[156]

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151 "Prohibition of defeat devices." 40 CFR § 86.1809-10. Availabe at: https://www.govinfo.gov/content/pkg/CFR-2013-title40-vol20/pdf/CFR-2013-title40-vol20-sec86-1809-10.pdf.

152 "In-Use Testing for Heavy-Duty Diesel Engines and Vehicles; Emission Measurement Accuracy Margins for Portable Emission Measurement Systems and Program Revisions." 40 CFR Part 86 [EPA–HQ–OAR–2004–0072; FRL–8539–3], Vol. 73, No. 50 / Thursday, March 13, 2008.

153 "Fuel Economy Testing and Labeling," EPA-420-F-14-015, p. 2.

154 *Id.*

155 Smithers Report, ¶ 52.

156 McConnell, Thomas G., "Simultaneous evaluation of multiple PEMS using an engine dynamometer emissions test cell" (2007). Graduate Theses, Dissertations, and Problem Reports. 4318. p. 88. available at https://researchrepository.wvu.edu/etd/4318.

- In a study commissioned by the European Commission to evaluate PEMS unit performance for RDE measurements, it was found that PEMS units typically utilized for light-duty vehicle RDE studies can introduce uncertainty of up to 43% when all the sources of uncertainty are considered.[157]
- A 2019 study comparing field PEMS and laboratory dynamometer emissions testing demonstrated the inherent variability of PEMS testing. Despite using the same vehicle, driver, and routes, and correcting the driving cycle for speed, grade and temperature, the researchers were not able to identically match the average CO_2 emissions for all runs. Overall by averaging the results, the field PEMS results were biased high compared with laboratory dynamometer testing, indicating that additional variables need to be considered.[158]

Mr. Smithers referenced two PEMS testing programs currently conducted by regulatory agencies to justify the reliability and accuracy of PEMS testing: the European Commission's RDE testing and the EPA and CARB heavy duty in-use compliance programs.[159] However, he ignored the codified procedures required by these programs, which include (1) verifying the PEMS unit against laboratory dynamometer equipment by running a test cycle on a dynamometer with a PEMS attached, and (2) applying adjustment factors to relate on-road PEMS testing results to certification dynamometer testing limits. These adjustment factors, explained further in Appendix E, are used to account for the variability inherent with PEMS on-road testing (traffic conditions, driving style, elevation change, fuel type, additional vehicle loading, etc.) and PEMS measurement uncertainty. Even though Mr. Smithers' testing conditions incorporated more variability, and more extreme conditions, than are allowed in existing regulatory PEMS testing programs, his data analysis failed to account for any of these uncontrolled factors.[160]

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157 Aliandro Varella, Roberto & Giechaskiel, Barouch & Sousa, Luis & Duarte, Gonçalo. (2018). Comparison of Portable Emissions Measurement Systems (PEMS) with Laboratory Grade Equipment. Applied Sciences. 8. 1633. 10.3390/app8091633. available at https://www mdpi.com/2076-3417/8/9/1633.

158 *See* Akard, Michael et al., "Comparison of Real-World Urban Driving Route PEMS Fuel Economy with Chassis Dynamometer CVS Results," SAE 2019-01-0762, 2019.

159 Smithers Report, ¶ 83.

160 In addition, Mr. Smithers conducted several tests at temperatures below the minimum specified operating temperature of the PEMS unit. Mr. Smithers testified that this was done after communication with the PEMS unit manufacturer, and that the manufacturer felt "comfortable" with this usage, but no documentation has been provided that can be used to verify the proper working condition of all of the components of his PEMS equipment during these test drives. Smithers Deposition, Vol. I, 239:22-241:21. The EPA PEMS calibrations and verifications regulations note that "[i]t may be necessary to limit the range of conditions under which the PEMS can be used….". 40 CFR § 1065.920 - PEMS calibrations and verifications.

6.2.2 PEMS Testing Could Result in Higher Emissions than Dynamometer Testing for a Variety of Reasons

Beyond measurement uncertainty, there are a variety of reasons why emissions during on-road PEMS testing can be higher than emissions measured during laboratory dynamometer testing, and that in turn make direct comparisons to the EPA's test cycle emissions standards incorrect. First, in-use road loads do not necessarily correspond to the loads programmed into a dynamometer because, among other things, on-road driving includes hills varying wind conditions, and the loaded vehicle weight may differ from that used in laboratory testing and can affect how much power is demanded by the engine.[161] Higher engine loads usually lead to higher emissions, so on-road driving could lead to higher emissions than if tested under laboratory conditions.

The PEMS system itself could add considerable weight on the vehicle which would result in higher engine load and likely higher emissions levels. For instance, the PEMS system used in the testing conducted in the West Virginia CAFEE study was 300 kg (661 pounds),[162] and was on top of the driver and any other occupants of the vehicle. Mr. Smithers testified that the total payload was 500lb to 800lb during his testing.[163] In contrast, vehicles are certified with 300lb additional payload.[164] With increased vehicle weight the engine will have to work harder, especially during accelerations and while climbing hills, and this can result in higher emissions.[165]

Second, Mr. Smithers used an ambient temperature probe purportedly to verify the outside air temperature during his PEMS testing. According to the photo found in Figure 10-41 of the Smithers Report, this probe was affixed to the test vehicle's window and above the vehicle at roughly 5 feet above the pavement. This affected the vehicle loading by increasing wind resistance (especially at high speed) due to the probe, rack, and other equipment fixed outside

161 On-road driving is understood to include significantly more variability in driving conditions and demands on the engine and after-treatment systems, and under certain driving conditions it is expected that NO_x and other emissions may "spike" as a result of increased engine load. *See* "Real-World Exhaust Emissions from Modern Diesel Cars," ICCT White Paper, page ii.

162 *See* Thompson Gregory J. et al., "In-Use Emissions Testing of Light-Duty Diesel Vehicles in the United States," Prepared for: International Council on Clean Transportation (ICCT), May 2014, p. 38 ("The payload of Vehicles A and B was representative of four adult passengers totaling 300kg when assuming 75kg per individual passenger (i.e. Vehicle A: 305kg, Vehicle B: 314kg), whereas Vehicle C's payload had to account for additional 230kg (i.e. 533kg).").

163 Smithers Deposition, Vol. I, 244:10-17.

164 CFR 40 § 86.129–00 "Road load power, test weight, and inertia weight class determination."

165 *See* Thompson, Gregory J. et al., "In-Use Emissions Testing of Light-Duty Diesel Vehicles in the United States," Prepared for: International Council on Clean Transportation (ICCT), May 2014, p. 38 ("The payload of Vehicles A and B was representative of four adult passengers totaling 300kg when assuming 75kg per individual passenger (i.e. Vehicle A: 305kg, Vehicle B: 314kg), whereas Vehicle C's payload had to account for additional 230kg (i.e. 533kg).").

the vehicle, creating more drag and, in turn, increasing engine load and likely emissions levels.

Notably, Mr. Smithers acknowledged that the fuel economy achieved during his highway on-road testing was approximately 10% lower than the stated highway fuel consumption of the Cruze diesel[166] and that "[e]missions can increase if the drive style is aggressive".[167] However, even with his own data showing that testing was conducted at higher loads and lower fuel economy, Mr. Smithers did not attempt to measure or adjust for the effect of increased engine loads on emissions.

6.2.3 Mr. Smithers' Test Methodology Did Not Account for Testing Variability and is Inconsistent with Standards Used for On-Road Emissions Testing

Mr. Smithers conducted more than 8,000 miles of on-road PEMS testing of a single, used MY2015 Diesel Test Vehicle.[168] His conclusions relied almost exclusively on the results of this testing.

Below, and notwithstanding my opinion that it is inappropriate to directly compare emissions generated by on-road testing and recorded by PEMS testing equipment to EPA standards that apply to laboratory test conditions captured by dynamometer testing equipment in the way that Mr. Smithers has, I describe the ways in which Mr. Smithers' PEMS testing methodology is inconsistent with industry best practices and regulatory procedures used for on-road emissions testing and yields unreliable and biased results.

Mr. Smithers failed to conduct basic engineering and scientific evaluations of his testing equipment and methodologies including:

(1) Verifying his PEMS test equipment against a laboratory calibrated test bench to understand the variability introduced by his PEMS equipment;[169,170]

(2) Duplicating runs of the same test cycle across multiple vehicles to understand the vehicle-to-vehicle variability;

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166 *See* Smithers Report, ¶ 102 ("Indeed, in the ambient temperature range from 68°F to 86°F, which is the window for the HWFET emissions test, fuel economy is measured to be 53.6 mpg on flat roads. This fuel economy is only about 10% lower than the fuel economy presented in the certification application on the HWFET, 59.8 mpg.").

167 *See* Smithers Report, ¶ 97.

168 *See* Smithers Report, ¶ 105 ("The 2015 Cruze diesel was tested over the course of 1,825 miles […] in city driving conditions.") *See also* Smithers Report, ¶ 108 ("The Cruze diesel was tested over 6,236 miles […] in steady highway driving conditions.").

169 "PEMS calibrations and verifications." 40 CFR § 1065.920.

170 Commission Regulation (EU) 2016/427, L 82/38.

(3) Duplicating runs of the same test route with the same vehicle to understand the test-to-test variability introduced by the vehicle and traffic conditions; and

(4) Using different test drivers over the same test route to evaluate the influence of drivers' style.

These fundamental evaluations would allow one to quantify the influence of important factors on the variability of testing results, and Mr. Smithers' failure to do so can lead to erroneous conclusions. Indeed, as Mr. Smithers acknowledged with respect to a PEMS test program, "[t]ests are typically repeated dozens of times, with careful attention paid to, among other things, the average cycle speed, ambient temperature, RPA, and road grade."[171] Notably, however, there is no evidence that Mr. Smithers conducted any of these types of robustness checks or conducted repetitive testing.

Given the lack of evidence that Mr. Smithers conducted any robustness checks, it is no surprise that equipment variability, test-to-test variability, and vehicle selection bias were also not discussed or accounted for by Mr. Smithers.

First, referring back to the four main robustness checks, Mr. Smithers' conclusions relied almost exclusively on results derived from his on-road PEMS equipment, yet he made no attempt to validate the accuracy of this equipment by testing it alongside dynamometer equipment in a laboratory setting as is required by regulatory PEMS testing programs cited by Mr. Smithers as evidence of the reliability and accuracy of PEMS testing. Because of known measurement uncertainty, the basic practice of cross-correlating PEMS equipment with laboratory dynamometer equipment is required by the European RDE limits for light-duty vehicles[172] and by the EPA and CARB heavy duty in-use compliance testing.[173]

Second, Mr. Smithers apparently did not conduct repeat test routes under the same ambient and vehicle driving conditions to then compare the results to assess the reliability and repeatability of his methodology. This is inconsistent with testing conducted by the University of West Virginia's Center for Alternative Fuels, Engines & Emissions in collaboration with the ICCT (West Virginia CAFEE Report) and cited by Mr. Smithers.

Third, and more significantly, Mr. Smithers tested *only one vehicle* and then purported to generalize his conclusions *to all vehicles* of the same make and model. The potential for selection bias that results from only testing a single in-use vehicle is a significant concern with Mr. Smithers' testing and alone renders his results unreliable. That problem is

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171 *See* Smithers Report, ¶ 91.

172 PEMS validation procedures require that PEMS are validated against laboratory CVS equipment and that NO_x measurements are within "± 15 mg/km [24 mg/mi] or 15 % of the laboratory reference, whichever is larger." COMMISSION REGULATION (EU) 2016/427 of 10 March 2016 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6). March 31, 2016.

173 40 CFR § 1065.920 - PEMS calibrations and verifications.

exacerbated because the Diesel Test Vehicle had maintenance issues that likely affected emissions measurements and certainly call into question the repeatability, reliability, and validity of his results.[174] By testing just a single diesel vehicle, neither Mr. Smithers nor other engineers would be able to determine whether that vehicle was representative or whether there may be any vehicle-specific reasons why his emissions readings were higher than the limits that Mr. Smithers applied. In addition, in the next section, I discuss the evidence which indicates that the Diesel Test Vehicle had issues, at minimum at the time of the multi-party inspection, with its emissions control system and abnormal dynamometer test results that would render it unrepresentative of Subject Vehicles, generally.

Fourth, Mr. Smithers did not conduct an analysis to evaluate the influence of the variability among different test drivers over the same test routes. Moreover, Mr. Smithers testified at deposition that he did not even have a written protocol for the drivers.[175]

Finally, I note that in order to justify the reliability and accuracy of PEMS testing, Mr. Smithers referenced the West Virginia CAFEE report.[176] However, the West Virginia CAFEE report used a more rigorous methodology to conduct such a comparison, cross-correlation testing (i.e., testing a vehicle on dynamometer using the dynamometer's emissions measurement equipment and the PEMS unit) to compare the operation and accuracy of the PEMS measurement equipment with laboratory emissions measurement equipment used for certification testing.

Moreover, the West Virginia CAFEE study carefully selected and characterized the test routes driven for PEMS data collection, and assessed potential sources of variability on these routes including: multiple drivers on the same route to assess driving style influences, different times of day to assess the effect of traffic conditions, and multiple test runs along the same route to assess other sources of variability. Mr. Smithers' failure to follow this same procedure, even for a subset of routes or an initial assessment of his methodology, renders his PEMS testing methodologically unsound. In contrast to these good engineering and test practices, Mr. Smithers did not conduct any dynamometer correlation testing or on-road repeatability testing to evaluate the accuracy or repeatability of his PEMS test equipment and methodology.

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174 *See* Wenzel, Thomas P. et al. 2000. "Some issues in the statistical analysis of vehicle emissions." *Journal of Transportation and Statistics* 3, pp. 5-6 (*e.g.* "Real-world vehicle emissions are highly variable. Emission variability from vehicle to vehicle spans several orders of magnitude, while the emissions of most vehicles will vary substantially with environment and driving conditions. Emissions of some vehicles are unrepeatable: different emissions occur from one test to another, even when test conditions are carefully controlled." and "The degree to which owners maintain their vehicles by providing tune-ups and servicing according to manufacturer schedules can affect the likelihood of engine or emissions control system failure and therefore tailpipe emissions.").

175 *See* Smithers Dep. Vol. 2, 287:5-288:22.

176 See Smithers Report, ¶ 83.

6.2.4 Mr. Smithers Over-Represents Extreme Temperature Conditions in his PEMS Testing

In his report, Mr. Smithers compared the results of his PEMS testing, by segment, to the EPA's FTP and HWFET standards for NO_x emissions, which are standards applied to carefully controlled laboratory testing conditions. For example, Mr. Smithers concluded that for city driving "[w]hen averaged over all tests, the [diesel test] vehicle emitted 288 mg/mile NOx, or 4.1 times the federal standard of 70 mg/mile"[177] and that for highway driving "[t]he average NOx emissions were found to be 220 mg/mile over the course of all those tests, or 2.4 times the federal standard of 90 mg/mile."[178]

As described further below, analysis of Mr. Smithers' PEMS data shows that he focused much of his testing on extreme temperature conditions that fall outside of the FTP and HWFET test cycle conditions, likely with added load on the engine from air conditioner use (or the windows down). The emissions standards associated with the EPA's Cold temperature CO and SC03 test cycles[179] reflect the fact that extreme temperature conditions (both cold and hot) are *expected* and understood by the EPA to result in increased emissions, all else being equal. However, Mr. Smithers tested at temperatures even lower than the Cold CO test and higher than the SC03 test cycles and continued to reference everything back to the limits set for dynamometer testing in the 68 to 86 °F temperature range.

Analysis of data from the Diesel Test Vehicle shows that Mr. Smithers conducted three series of PEMS tests in the spring of 2016, in the summer and fall of 2018, and in the winter of 2018-2019. Figure 6-3 presents the cumulative test distance (in miles) for all of the PEMS data collected by Mr. Smithers associated with the Diesel Test Vehicle, binned by the average ambient temperature of each segment. The figure shows that during his 2016 testing, Mr. Smithers conducted most of the driving of his Diesel Test Vehicle in temperatures in the 60 °F to 95 °F range, while in 2018 and 2019 he focused on both low and high temperature conditions. Mr. Smithers' 2018 and 2019 testing had a very limited amount of driving conducted in temperatures in the 45 °F to 65 °F range.[180]

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177 Smithers Report, ¶ 105.

178 Smithers Report, ¶ 108.

179 See Appendix E. Cold CO emissions limits do not include NO_x limits.

180 Analysis is based on Mr. Smithers' weather probe temperature. For entries for which Mr. Smithers did not report weather probe temperature data, the vehicle's modeled outside air temperature data was used instead.

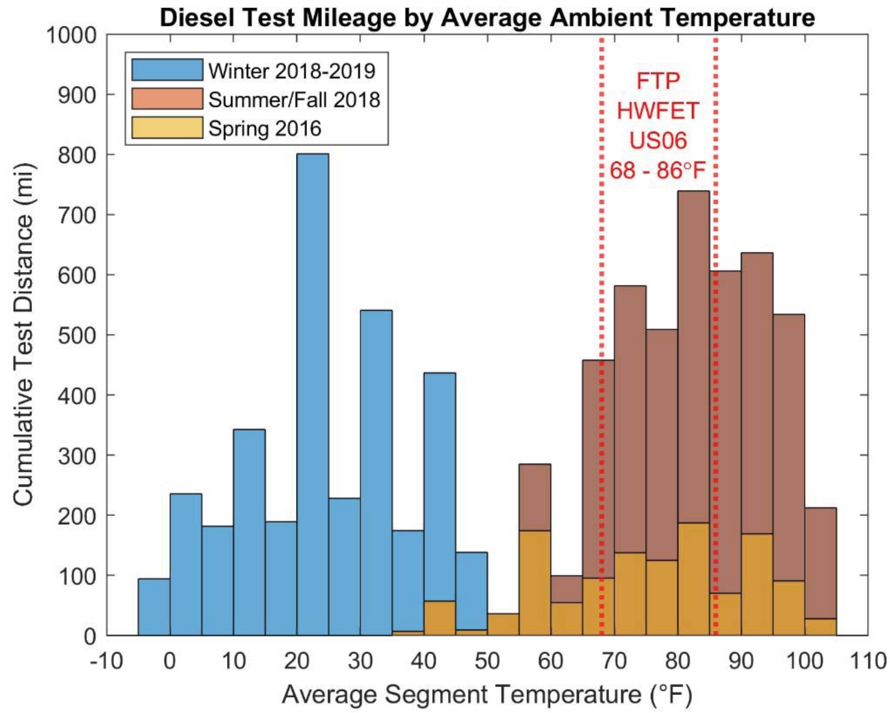

Figure 6-3 Cumulative test distance, binned by average ambient temperature, for all the PEMS data collected with the Diesel Test Vehicle by Mr. Smithers.

The same analysis was conducted for the Gasoline Test Vehicle and results show that (1) the Gasoline Test Vehicle was not driven up to 105 °F and (2) the Gasoline Test Vehicle mileage distribution was different from the Diesel Test Vehicle mileage distribution indicating that the environmental conditions for the two test vehicles were different during testing (Figure 6-4).

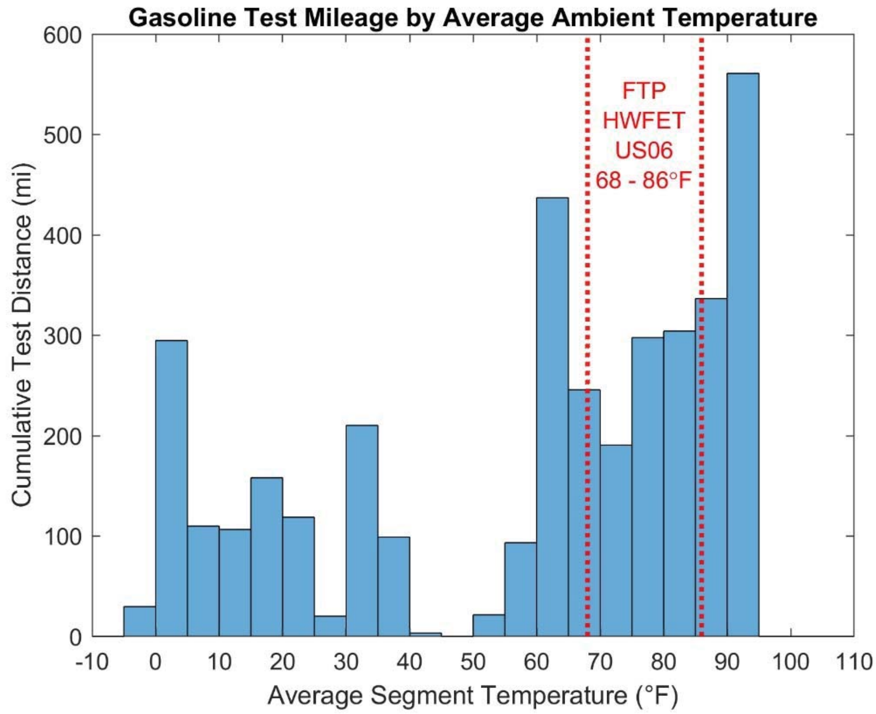

Figure 6-4 Cumulative test distance, binned by average ambient temperature, for all the PEMS data collected with the Gasoline Test Vehicle by Mr. Smithers.

In order to further analyze Mr. Smithers' PEMS data to understand how the distribution of ambient temperature conditions influenced the emissions levels he reported for the Diesel Test Vehicle, I calculated distance-weighted NO_x emissions binned by average ambient temperature, using the same data segmentation employed by Mr. Smithers.[181] The results are summarized in Figure 6-5 and are consistent with the segment scatterplots presented in Figures 9-7 and 9-9 of Mr. Smithers' report:[182] that is, NO_x emissions are constant in the 10 °F to 90 °F range (which is even broader than the entire range for which vehicle manufacturers are required to demonstrate continuity of emissions levels). Mr. Smithers's emissions levels are elevated at the ambient temperature extremes (both very hot and very cold) for conditions that are covered by disclosed AECDs or Supplemental FTP testing conditions. It should also be noted that this analysis was conducted using Mr. Smithers' data and therefore each temperature bin includes PEMS test segments that are uncontrolled for

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181 The average segment temperature as recorded by the weather probe associated with the PEMS unit was compared against the reported NO_x emissions for the segment. For the segments that had unreliable or missing weather probe temperature data (as identified by Mr. Smithers), recorded data from the test vehicle's modeled outside air temperature data was used. While the temperature may vary along a test segment, the variation is expected to be small given that the average segment length, as constructed by Mr. Smithers, is less than 12 miles. Therefore, it is possible that at a more granular level some of the data might move one or two bins to the left or right, but on a global level the data showed good continuity, indicating that this effect would be minor.

182 Smithers Report, ¶¶ 112, 118.

other variables that may influence emissions (e.g., road grade, DPF regeneration, cold starts, etc.). These segments are therefore not representative of average conditions (for instance, Mr. Smithers drove several very long uphill segments that are not typically encountered during everyday driving by many drivers).

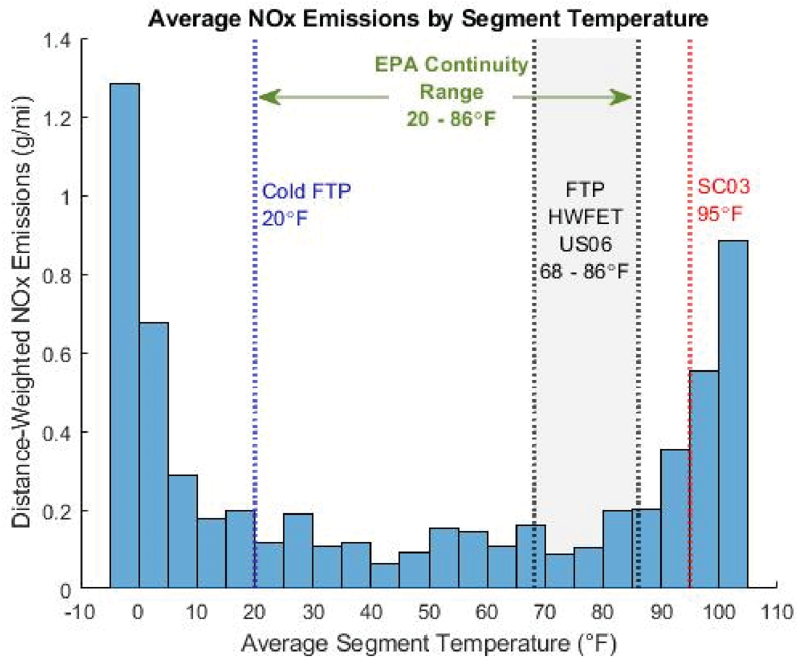

Figure 6-5 Distance-weighted average NO_x emissions for test segments with average ambient temperatures in the ranges shown along the horizontal axis.

This choice of testing conditions renders Mr. Smithers' emissions data unrepresentative of average vehicle usage, as his testing focused on extreme conditions that are not typical of conditions encountered by drivers. For instance, when evaluating emissions limits, the EPA takes into account a plethora of factors including how vehicles are used on road so that test procedures are representative of typical or real-world vehicle usage.[183,184] As one example, in preparation for the 2017-2025 light duty vehicle GHG emissions standards and corporate average fuel economy (CAFE) standards, the EPA used the Motor Vehicle Emission Simulator (MOVES) model[185] to estimate the national average vehicle miles traveled (VMT)

183 40 CFR Parts 86 and 600 – Fuel Economy Labeling of Motor Vehicles: Revisions To Improve Calculation of Fuel Economy Estimates; Final Rule, dated December 27, 2006.

184 40 CFR Parts 86 and 600 – Fuel Economy Labeling of Motor Vehicles: Revisions To Improve Calculation of Fuel Economy Estimates; Final Rule, dated December 27, 2006.

185 "EPA's Motor Vehicle Emission Simulator (MOVES) is a state-of-the-science emission modeling system that estimates emissions for mobile sources at the national, county, and project level for criteria air pollutants, greenhouse gases, and air toxics." Available at: https://www.epa.gov/moves. Accessed on June 5, 2020.

as a function of ambient temperature. This analysis, shown in Figure 6-6 below, is relevant to the analysis of Mr. Smithers' data because it provides a distribution of average mileage driven as function of temperature in the United States. These data show that 68.75% of VMT occurs between 40 °F and 80 °F, 21.95% of VMT occurs below 40 °F, and only 9.69% of VMT occurs above 80 °F.[186]

VMT	tempAvg	Fraction	Temp Range VMT Fraction
1181.656796	-25	0.00000157	
4400.79767	-20	0.00000585	
12905.217	-15	0.00001714	
40874.20742	-10	0.00005429	
174939.1854	-5	0.00023235	
762497.0884	0	0.00101274	
1915732.576	5	0.00254446	
4924729.91	10	0.00654097	
12353230.63	15	0.01640743	0.21958689
23259876.93	20	0.03089353	(< 40 deg F)
31418211.75	25	0.04172934	
41033016.47	30	0.05449962	
49426375.28	35	0.06564760	
55404781.78	40	0.07358805	
60396251.48	45	0.08021767	
63018086.25	50	0.08369996	
68380740.42	55	0.09082259	
73176481.47	60	0.09719224	0.68343503
72473451.14	65	0.09625848	(> 40 deg F, < 80 deg F)
67073984.17	70	0.08908697	
54637578.9	75	0.07256906	
39382139.05	80	0.05230695	
24182451.73	85	0.03211888	
7635253.418	90	0.01014106	
1203687.536	95	0.00159873	0.09697809
593360.565	100	0.00078810	(>80 deg F)
18352.30991	105	0.00002438	
752904571.9	TotalVMT	1.00000000	

Figure 6-6 MOVES data of vehicle miles traveled (VMT) as function of ambient temperature.[187]

Thus, data on typical driving indicates that most of the driving in the U.S. happens in the temperature range that was least surveyed by Mr. Smithers. As a result, Mr. Smithers' conclusions about "average" emissions are of little value since they are based on driving

186 EPA. "Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards." EPA-420-R-12-901. August, 2012. p. 5-87.

187 EPA. "Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards." Table 5-28 EPA-420-R-12-901. August, 2012. Table 5-28.

conditions that are heavily-weighted towards cold and hot conditions that are not representative of total vehicle miles traveled in the United States.

A sound and reliable vehicle test program intended to evaluate on-road performance in typical driving conditions, in a comprehensive manner should reflect temperature conditions that are typically encountered by drivers. To check whether Mr. Smithers' testing did so, I compared the percentage of miles driven by the Diesel Test Vehicle (shown in blue), binned by the average ambient temperature of each test segment, against the EPA's estimate of annual VMT by temperature as reported in Figure 6-6 above and shown in orange below.

The results of my analysis, shown in Figure 6-7, demonstrate that compared to real-world driving, Mr. Smithers conducted a much greater proportion of his on-road testing of the Diesel Test Vehicle at extreme temperatures, while moderate temperatures that account for the majority of annual VMT in the U.S. were under-sampled. For example, while only 2.7% of annual VMT are driven at temperatures less than 20 °F, 13.0% of Mr. Smithers' testing of the Diesel Test Vehicle was conducted at these temperatures. Likewise, 9.3% of Mr. Smithers' testing was conducted at temperatures greater than 95 °F, as compared to just 0.2% of real-world VMT. Notably, the FTP, HWFET, and US06 emissions test cycle protocols, as discussed in Appendix E, require testing to be performed in a controlled laboratory environment with temperatures between 68 °F and 86 °F and it is understood that emissions can change significantly when testing at lower or higher temperatures (all else being equal). Conversely, only 27% of Mr. Smithers' on-road testing of the Diesel Test Vehicle is within this certification range. Therefore, it is unreasonable to draw conclusions about average emissions performance of the Diesel Test Vehicle that Mr. Smithers evaluated without first accounting for the effects of the skewed temperature distribution of his testing, which Mr. Smithers did not do.

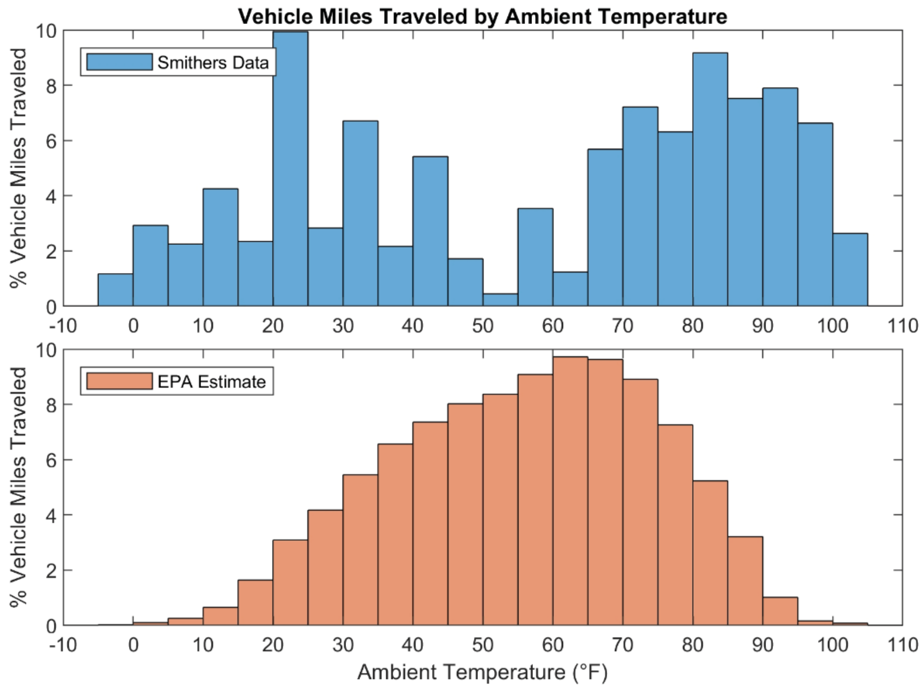

Figure 6-7 Percentage of miles driven in each temperature range in Mr. Smithers' PEMS data for the Diesel Test Vehicle (blue), and according to an EPA estimate of annual U.S. vehicle miles driven.

To facilitate a more meaningful evaluation of Mr. Smithers' test data, I re-weighted his test segments in a two-step process according to a more realistic distribution of test conditions. First, the city and highway segments (as identified by Mr. Smithers) were re-weighted based on a 55%/45% city/highway mileage split, as employed by the EPA in calculations of combined fuel economy.[188] Of all of Mr. Smithers' test miles, 23% were marked by Mr. Smithers as city segments, while 77% were marked as highway segments. Thus, the redistribution increased the relative proportion of city miles compared with Mr. Smithers' analysis.[189]

Second, to account for the unrepresentative distribution of test temperatures in Mr. Smithers' on-road testing, each test segment was binned according to the average segment temperature, and each bin was then weighted by the EPA estimated distribution of VMT by temperature shown in Figure 6-7.[190]

188 U.S. Department of Energy. "Model Year 2015 Fuel Economy Guide." Available at: https://www fueleconomy.gov/feg/pdfs/guides/FEG2015.pdf.

189 For the purposes of this analysis, I adopt Mr. Smithers' categorization of "city" and "highway" segments, notwithstanding my primary opinion that Mr. Smithers' segmentation is biased, as I discuss in Section 6.4.2.

190 An individual estimate for city and highway conditions was not calculated because the VMT by temperature distribution calculated by EPA does not discern city versus highway mileage.

The analysis resulted in an estimated average NO_x emissions value of 148 mg/mi[191] (2.1x the FTP standard, 1.6x the HWFET standard, and below the US06 and SC03 limits) as opposed to Mr. Smithers' claims that the Cruze test diesel achieved NO_x emissions of 288 mg/mile on city[192] and 220 mg/mile on highway driving.[193] That level is reasonable given the many other factors that were overlooked by Mr. Smithers that are known to impact emissions, including, but not limited to, known maintenance issues with the Diesel Test Vehicle discussed in Section 6.3.1, no "correction" for real world driving conditions as compared to test cycle dynamometer testing (additional vehicle weight, weather conditions, driving style, traffic, etc.), PEMS measurement equipment uncertainty, PEMS variability, the use of the air conditioner, and road grade.

Finally, given that the analysis of Mr. Smithers' PEMS data shows that 25% of his testing was conducted at temperatures above 85 °F (in comparison, VMT data for the US shows that only 4.5% of miles are driven above 85 °F on average), it is likely that this testing was conducted with added load on the engine from air conditioner use (or the windows down). Mr. Smithers' report is noticeably silent on his use of air conditioning during testing (though he testified that the default condition for air conditioning was "on" and he did not control for air conditioning usage) and he did not collect data regarding air conditioner status even though the tool he used to log data appears to be capable of logging this information.[194,195] Both air conditioning use and open windows can impart additional load on a vehicle's engine which can increase NO_x emissions.[196]

6.2.5 Mr. Smithers' Ignores the EPA Test Cycle for High Ambient Temperatures and Air Conditioner Use

In fact, as discussed further in Appendix E, this is why the EPA created and uses the SC03 test cycle which is conducted at 95°F with the air conditioner on. The emissions standards for the SC03 are significantly higher than the FTP and HWFET standards to account for the impact of operating the vehicle at higher temperature and use of air conditioning.[197] Even

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191 I calculated average NO_x on a city-highway combined basis because a VMT distribution separated for highway and city driving for the US was not available.

192 Smithers Report, ¶ 105.

193 Smithers Report, ¶ 108.

194 Smithers Deposition, Vol. I, 250:10-252:4.

195 http://hemdata.com/products/dawn/eobd

196 Nam, E., "Understanding and Modeling NOx Emissions from Air Conditioned Automobiles," SAE Technical Paper 2000-01-0858, 2000, https://doi.org/10.4271/2000-01-0858.

197 Additionally, as a further demonstration of the importance to properly account for actual driving conditions (and how they deviate from nominal conditions), the European RDE program requires PEMS emissions to be divided by 1.6 when testing under "extended temperature conditions," which are

though the EPA has a separate test for high temperature conditions with air conditioning use, and the European RDE protocol introduces an adjustment factor for low and high temperature test conditions, Mr. Smithers made no attempt to adjust or consider the impact of known temperature and air conditioning influence on emissions. To the contrary, he used the FTP and HWFET standards for *all* of his comparisons, even as to those test segments far outside the ambient temperature range or speeds used for those test segments.

6.3 Mr. Smithers' PEMS Testing Methodology was Flawed and Produced Biased Results

6.3.1 Evidence Indicates that the Diesel Test Vehicle Was Not Representative of the Subject Vehicles

As described above, Mr. Smithers did not address or consider the possible influence of vehicle-to-vehicle variability on his PEMS test results, and did not evaluate whether the Diesel Test Vehicle was representative of its type. Instead, Mr. Smithers chose to conduct over 8,000 miles of PEMS testing on a single Cruze diesel vehicle (the Diesel Test Vehicle). While testing a single vehicle can yield information about that *specific vehicle's* performance, the performance of that vehicle cannot be assumed to represent the performance of all vehicles of the same make and/or model year. The operating condition of a vehicle is critically important to the emissions performance of that vehicle, and the results of one vehicle may not be representative of an entire population of a vehicle model, especially if the vehicle tested is not in proper working order.[198] Moreover, based on the available information, there are engineering reasons indicating that the Diesel Test Vehicle used by Mr. Smithers was not representative of the Subject Vehicles.

6.3.1.1 Timeline of Maintenance and Testing of the Diesel Test Vehicle

Before describing some of the evidence indicating that the Diesel Test Vehicle had issues that rendered its emissions unrepresentative of the Subject Vehicles generally, I first present a chronology of key events associated with the Diesel Test Vehicle and Mr. Smithers' testing. Figure 6-8 below presents a timeline of the mileage accumulation and key events on the Diesel Test Vehicle, compiled by combining data produced by Mr. Smithers with

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temperatures between 19.4-32°F and 86-95°F. See Commission Regulation (EU) 2016/427, available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32016R0427 and Commission Regulation (EU) 2016/646, available https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016R0646

198 By contrast, and for example, the EPA requires multiple vehicles to be tested at pre-determined intervals as part of its in-use testing program that evaluates the performance of a class of vehicles.

information included in the CarFax report associated with the Diesel Test Vehicle.[199] As shown in the timeline:

May 2016 -- Vehicle Purchase: Plaintiffs' counsel purchased the Diesel Test Vehicle as a Certified Pre-Owned (CPO) vehicle, at which time it had accumulated approximately 16,290 miles.[200] The Diesel Test Vehicle was purchased by its first owner around March of 2015, and records show that it received three vehicle services before it was purchased by Plaintiffs' counsel.

May 25, 2016 through June 8, 2016 -- Initial Series of PEMS Testing: Shortly after acquiring the Diesel Test Vehicle, Mr. Smithers conducted his first series of on-road PEMS evaluations for which he produced data accounting for approximately 1,300 miles of driving (approximately 15% of total PEMS test mileage).[201]

October, 2016 -- Recall Issued: General Motors issued Recall Number #N150594 in October of 2016, which included the replacement of the NO_x position 1 sensor (upstream NO_x sensor).[202]

June 2016 through March 2018 -- No Vehicle Testing: Following his 2016 testing, Mr. Smithers did not conduct additional PEMS testing until August 2018, over 26 months later. In January 2018, 18 months after Mr. Smithers' first set of PEMS testing, records show that the Diesel Test Vehicle accumulated approximately 3,510 miles since it was purchased (based on mileage reading available through the Carfax report).[203] Therefore, approximately 2,150 miles (over 61%) of the miles driven since the purchase of the Diesel Test Vehicle were not accounted for by Mr. Smithers and Mr. Smithers testified that the vehicle was stored and "exercised" but could not confirm the details of how, when, or what distances the vehicle was driven during this period of time.[204] The Carfax report does not include details of how the Diesel Test Vehicle was used and maintained during this time span. In deposition, Mr. Smithers testified that, prior to resuming testing in March 2018, he believes the fuel in the Diesel Test Vehicle was likely drained and replaced, the oil was changed, and some filters were replaced, although he was uncertain about details. He did not believe the DEF was changed before resuming testing.[205]

May 2017 -- Recall Issued: General Motors issued Recall Number #N151645630 on May 16, 2017, this recall superseded Recall #N150594 issued in October 2016 and

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199 Smithers Report, Appendix 12.2.

200 Smithers Report, ¶ 72 and Appendix 12.2.

201 Smithers Production Files, "Processed and Analyzed Cruze Diesel Data."

202 https://static nhtsa.gov/odi/tsbs/2016/MC-10130676-9999.pdf

203 CarFax Report obtained by Exponent on 2/5/2020.

204 Smithers Deposition, Vol. I, 176:19-180:19.

205 Smithers Deposition, Vol. I, 176:19-180:19.

included the replacement of the NO_x position 1 sensor (upstream NO_x sensor already included in the previous recall) and related software updates on the Diesel Test Vehicle.[206] According to the records produced by Mr. Smithers, Mr. Smithers elected not to apply this recall to the Diesel Test Vehicle.

March 13 and 14, 2018 -- Dynamometer Testing: The Diesel Test Vehicle underwent dynamometer testing, including the US06 (conducted March 13) and the FTP (conducted March 14) test cycles at the Transportation Research Center (TRC). There are no produced records of maintenance on the Diesel Test Vehicle between the purchase date in May of 2016 and the dynamometer testing conducted in March of 2018.

March 15, 2018 -- NO_x Sensor Replacement: Following dynamometer testing of the US06 and FTP test cycles, and according to records produced by Mr. Smithers, the downstream NO_x sensor on the Diesel Test Vehicle was replaced on March 15, 2018, the day after the FTP-75 dynamometer test.[207] The sensor appears to have been replaced by one of Mr. Smithers's colleagues, not by a GM dealership or certified facility.[208] There are no produced records describing the issue that caused Mr. Smithers to replace the downstream NO_x sensor at this time. However, Mr. Smithers testified that the sensor was replaced as a result of a MIL light illumination (check engine light) that occurred during the warm-up cycle for the HWFET dynamometer test.[209] Mr. Smithers did not provide any documentation of the MIL light incident, such as data from the vehicle's ECU or from an OBD scanner.

March 16 and 22, 2018 -- Dynamometer Testing: The Diesel Test Vehicle underwent additional dynamometer testing. In particular the Diesel Test Vehicle underwent HWFET (conducted March 16), a non-compliant SC03[210] (conducted on March 19), and the Cold FTP (conducted March 22) test cycles, also at TRC.

August 21, 2018 through December 5, 2018 -- Second Series of PEMS Testing: Mr. Smithers conducted a second series of on-road PEMS evaluations using the Diesel Test Vehicle in warm and hot conditions. Test data for approximately 3500 miles of driving was produced from this time period (approximately 45% of total PEMS test

206 https://my.gm.com/recalls?vin=1G1P75SZ4F7153752, accessed June 6, 2020. https://static nhtsa.gov/odi/tsbs/2018/MC-10143415-9999.pdf

207 "Cruze Vehicle Modification Summary.xlsx" document produced by Mr. Smithers, which outlines modifications made to the Diesel Test Vehicle.

208 Smithers Deposition, Vol. I, 190:18-191:17.

209 Smithers Deposition, Vol. I, 189:11-190:8.

210 Smithers Deposition, Vol. I, 191:22-193:23. Mr. Smithers testified that on March 19th 2018 TRC ran an SC03 test without the "solar array capable of simulating the load of sunlight on the vehicle." Mr. Smithers decided not to produce the test results and not to mention this test in his original report because the test was not compliant with the EPA regulations.

mileage). Again, plaintiffs produced no records about how the vehicle was stored or maintained from March until August.

December 16, 2018 through February 14, 2019 -- Third Series of PEMS Testing: Mr. Smithers conducted a third series of on-road PEMS evaluations using the Diesel Test Vehicle in cold conditions and logged approximately 3,300 miles (approximately 40% of total PEMS test mileage).

Figure 6-8 Timeline of mileage accumulation and key events associated with the Diesel Test Vehicle.

6.3.1.2 Mr. Smithers' Dynamometer Testing of the Diesel Test Vehicle Indicate Potential Issues with the Diesel Test Vehicle

The results of the dynamometer tests conducted on the Diesel Test Vehicle contained "red flags" that call into question whether there may be vehicle-specific maintenance issues that resulted in emissions readings across Mr. Smithers' dynamometer and PEMS testing being higher than they otherwise would have been if the vehicle was in proper working order. Figure 6-9 below compares the results of the dynamometer tests conducted by TRC on the Diesel Test Vehicle to the corresponding tests of the diesel Cruze conducted by GM for certification purposes.[211] The data show that the NO_x values found for the Diesel Test

[211] GMCOUNTS000812193.

Vehicle were significantly higher than the GM certification data for the FTP test cycle (2.6 times higher) and the US06 test cycle (2.4 times higher).

Notably, in the FTP test conducted by TRC, the Diesel Test Vehicle achieved 0.08 g/mi of NO_x over the test cycle, which would make the vehicle non-compliant with the EPA's Tier2 Bin5 emission limits (0.07 g/mi of NO_x) and cannot be explained by the alleged defeat devices.[212,213] [redacted]

These high FTP results were a red flag and they would have resulted in the Diesel Test Vehicle not passing the EPA in-use verification test regardless of what the emissions were on any given "portion" of the test cycle, or the vehicle's performance on other certification tests like the HWFET test cited by Mr. Smithers at deposition.[217] According to the EPA, only 3.9% of MY2014 vehicles and 4.0% of MY2015 vehicles with low mileage (10,000 to 50,000 miles) fail the FTP as part of the in-use verification program (IUVP) testing[218] and therefore the results that Mr. Smithers obtained were not average.

212 Moreover, although the NO_x emissions results of the FTP test on the Diesel Test Vehicle (0.08 g/mi) was numerically close to the 0.07 g/mi emissions standard, the Diesel Test Vehicle result does not include the deterioration factor (DF) and the infrequent regeneration adjustment factor (IRAF). To account for the addition of DF and IRAF, the measured emissions need to be *below* the emissions standard, as is the case for GM's NO_x certification results for the FTP, which are less than half of the FTP emissions standard. Mr. Smithers completely ignored this fundamental issue in his report when he states "[t]he result from the FTP-75, at 78 mg/mile, is slightly over the standard of 70 mg/mile but not enough to substantially impact the expected on-road results," and in Table 10-10 where he erroneously reported the "Composite NO_x mg/mile" for the Diesel Test Vehicle as 35 mg/mile on the FTP. *See* Smithers Report, ¶ 132 and Table 10-10.

213 Even if a vehicle passes all other certification tests, failing one will make the vehicle non-compliant.

214 [redacted]

215

216

217 Smithers Deposition, Vol. I, 223:4-16.

218 "2014-2017 Progress Report Vehicle Engine Compliance & Activities," *Environmental Protection Agency*, p. 57. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100WKFC.pdf.

[redacted]

As shown in the timeline above, after obtaining abnormal results on the US06 and FTP test cycles, Mr. Smithers replaced the Diesel Test Vehicle's downstream NO_x sensor. At a minimum, these results and the downstream NO_x sensor replacement call into question the representativeness of the PEMS testing Mr. Smithers conducted prior to this repair. Inexplicably, Mr. Smithers did not repeat the FTP test cycle after the sensor replacement to determine whether (A) this repair resulted in emissions test results compliant with the FTP standard or (B) if the downstream NO_x sensor had produced uncharacteristic PEMS results in prior on-road testing. Moreover, and as described further below, an exhaust leak was observed at the location of the downstream NO_x sensor at the multiparty inspection conducted in February 2020, suggesting that the on-road tests conducted by Mr. Smithers *after* the NO_x sensor replacement may also be unrepresentative of the Subject Vehicles in general. Interestingly, Mr. Smithers did not conduct dynamometer testing on the Gasoline Test Vehicle. Even though Mr. Smithers attempted to compare the PEMS results between the Diesel Test Vehicle and the Gasoline Test Vehicle, he made no attempt to evaluate and understand how each of the vehicles compared to its certification limits when operated on a dynamometer, before attempting to compare PEMS results.

[redacted]

219 [redacted]

220 [redacted]

[redacted]

6.3.1.3 Inspection of the Diesel Test Vehicle Revealed Multiple Maintenance and Repair Issues

During the February 28, 2020 multiparty inspection, Exponent identified multiple maintenance and repair issues with the Diesel Test Vehicle that render it non-representative of the Plaintiffs' proposed class and have the potential to adversely affect the engine or after-treatment systems performance and, consequently, the reliability of Mr. Smithers' test results.

6.3.1.3.1 Malfunction Indicator Light Illuminated

A readily apparent issue that manifested right away during the multiparty inspection on February 28, 2020 was that the Diesel Test Vehicle had its "Check Engine Light" (i.e., the Malfunction Indicator Light (MIL)) steadily illuminated, as shown in Figure 6-11 below. The fact that the MIL light was illuminated indicates that the Diesel Test Vehicle had a fault in the engine or a component or system that could affect the vehicle emission levels.[221]

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[221] Halderman, James D. Automotive Technology: Principles, diagnosis, and service. Prentice Hall, 2009, p. 960.

According to the EPA, the illuminated MIL indicates that the vehicle has a problem and that because of the issue, the vehicle could be wasting fuel and polluting the air.[222]

Figure 6-11 Photograph of the Diesel Test Vehicle taken during the multiparty inspection on February 28, 2020.[223] Notice that the vehicles orange malfunction indicator light (a k.a. check engine light) is illuminated on the left side of the instrument panel.

It is not only automotive best practice but also common knowledge that check engine light issues should be addressed as quickly as possible, in part to avoid excessively polluting the environment. In many states, including California where Mr. Smithers' office is located and where some of his on-road testing was conducted, the presence of an illuminated MIL constitutes an automatic failure of a smog check test, which can sometimes prohibit a vehicle from being registered for on-road use, until fixed. However, it is my understanding that the vehicle was not registered because Mr. Smithers elected not to apply the recall and therefore the vehicle could not pass the California smog test and that the check engine light had no bearing on that decision.[224]

222 "What does it mean if the light turns on while I'm driving? If the light comes on and stays on, your car may not be operating properly and could have a condition which wastes fuel, shortens engine life, or could lead to expensive repairs if left unaddressed. It could also be polluting the air." See EPA Consumer Information Bulletin, EPA420-F-00-041, September 2000.

223 GMCOUNTS000899291.

224 PLAINTIFF004867

6.3.1.3.2 Diagnostic Trouble Codes Cleared

Given the issues experienced by the Diesel Test Vehicle described throughout this section, it is especially important to understand if and when any diagnostic trouble codes (DTCs)[225] presented during Mr. Smithers' on-road PEMS testing. However, as detailed in Appendix 12.4 of Mr. Smithers' report, he chose not to record DTC data for the Diesel Test Vehicle (although, notably, he recorded these data for the Gasoline Test Vehicle) and as described further below, the multiparty inspection in February 2020 revealed that the DTC history for the Diesel Test Vehicle was reset or "cleared" shortly prior to the multiparty inspection. A sound and reliable vehicle test program would have recorded DTCs consistently and regularly throughout the testing process, confirmed the effects of any necessary repairs on emissions test results, and would not have ignored the influence of these or other vehicle issues on the test results.

More specifically, during the multiparty inspection, Exponent used a General Motors GDS2 scan tool[226] to communicate with the Diesel Test Vehicle's computer system and read the DTCs, including the codes that were responsible for illuminating the check engine light. From the scan, Exponent not only identified potential issues with the Diesel Test Vehicle's emission system, described below, but also found indications that electronic evidence had been cleared from the vehicle's computer system shortly before the inspection.

As shown in Figure 6-12, nine different DTCs were found stored in the Diesel Test Vehicle's computer memory. The trouble code that caused the check engine light to be illuminated was identified as "P21DD Reductant Tank Heater 1 Low Current," which pertains to a fault in the vehicle's SCR exhaust after-treatment system responsible for reducing emissions of NO_x.[227] Many, if not all, of the potential causes for this P21DD trouble code can affect the performance and emissions of the Diesel Test Vehicle and, under certain conditions, they can cause elevated levels of NO_x emissions. If the problem that caused the P21DD trouble code was present during Mr. Smithers' emissions testing, as it was during the multiparty inspection, then his emission test results, particularly those pertaining to NO_x emissions, are unreliable.[228] I have seen no physical or electronic evidence proving that the onset of the

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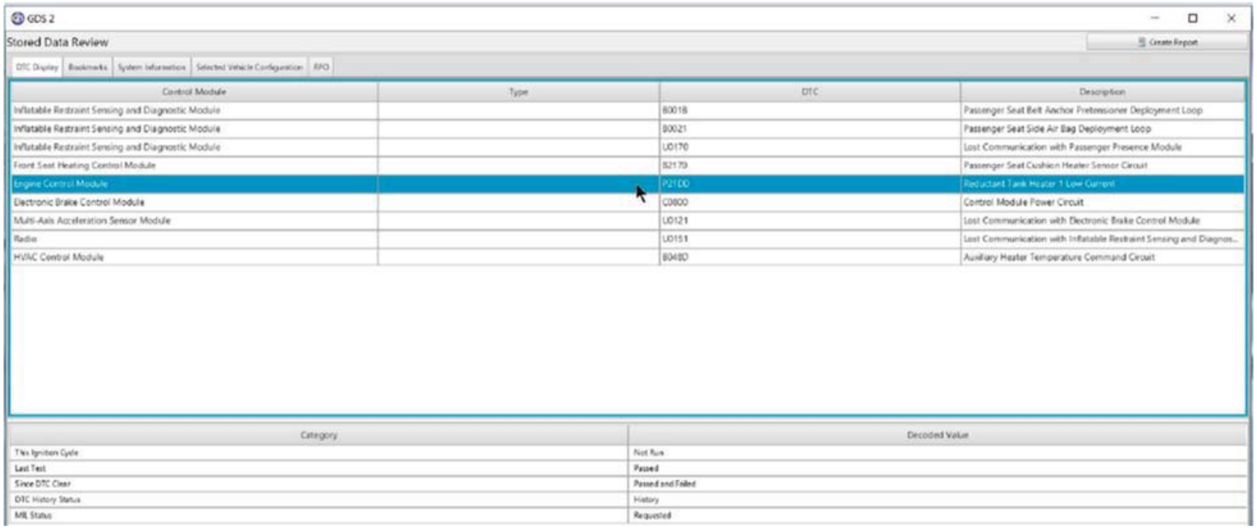
225 DTCs are generated by the onboard computer diagnostic and are used to diagnose potential vehicle malfunctions.

226 A scan tool is a tool that connects to the vehicle, typically at the vehicles OBD Data Link Connector and communicates with the vehicles computer system.

227 More specifically, the reductant tank heater #1 helps maintain proper temperature of diesel exhaust fluid (DEF). A failure of the heater system has the potential to cause the DEF to operate at an improper temperature and can cause the fluid to freeze (and subsequently not be injected) at temperatures below 0°C, rendering the NO_x reduction system inoperable. According to General Motors' service information, potential causes for the P21DD include issues with the vehicles reductant heater, wiring, or the Glow Plug module. See General Motors Service Information for VIN 1G1P75SZ4F7153752, P21DD Reductant Heater 1 Current Low Circuit/System Testing.

228 Especially during cold weather testing when it's possible to form ice in the DEG tank,

P21DD trouble code was after the completion of Mr. Smithers' emissions testing and the issue of the DEF tank heater could be related to Mr. Smithers' cold testing that included temperatures around 0 °F as at these temperatures DEF can crystallize.[229] The fact that there were instances of high SCR conversion during cold testing does not mean that the SCR system was always working as it should as implied by Mr. Smithers.[230]



Control Module	Type	DTC	Description
Inflatable Restraint Sensing and Diagnostic Module		B0018	Passenger Seat Belt Anchor Pretensioner Deployment Loop
Inflatable Restraint Sensing and Diagnostic Module		B0021	Passenger Seat Side Air Bag Deployment Loop
Inflatable Restraint Sensing and Diagnostic Module		U0170	Lost Communication with Passenger Presence Module
Front Seat Heating Control Module		B2179	Passenger Seat Cushion Heater Sensor Circuit
Engine Control Module		P21DD	Reductant Tank Heater 1 Low Current
Electronic Brake Control Module		C0800	Control Module Power Circuit
Multi-Axis Acceleration Sensor Module		U0121	Lost Communication with Electronic Brake Control Module
Radio		U0151	Lost Communication with Inflatable Restraint Sensing and Diagnos...
HVAC Control Module		B048D	Auxiliary Heater Temperature Command Circuit

Category	Decoded Value
This Ignition Cycle	Not Run
Last Test	Passed
Since DTC Clear	Passed and Failed
DTC History Status	History
MIL Status	Requested

Figure 6-12 List of diagnostic trouble codes (DTCs) stored in the Diesel Test Vehicle's computer system at the start of the multiparty inspection on February 28, 2020.[231] Notice that there is P21DD Reductant Heater 1 Low Current fault stored and that the MIL status is "Requested" (i.e., the check engine light is commanded on).

The "freeze frame" data pertaining to the P21DD code presented in Figure 6-12 shows that the DTCs of the Diesel Test Vehicle used by Mr. Smithers had been cleared 20 miles before the multiparty inspection.[232,233] In his deposition, Mr. Smithers admitted that a member of his staff cleared the DTCs.[234] Freeze frame data also shows that the first recorded P21DD malfunction occurred 19 miles before the multiparty inspection (i.e., the first record of P21DD fault remaining in the Diesel Test Vehicle's computer memory occurred within one

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229 Peak BlueDEF spec sheet.

230 With respect to test segments conducted at ambient temperatures below the freezing point of DEF, Mr. Smithers testified that "it's very clear…that the SCR is functioning with a high degree of efficiency. So the DEF isn't frozen, and the system is injecting." Smithers Deposition, Vol. II, 347:1-4.

231 Smithers 2015 Diesel Cruze 1G1P75SZ4F7153752 Diagnostics Report, p. 302.

232 Smithers 2015 Diesel Cruze 1G1P75SZ4F7153752 Diagnostics Report, p. 255. Smithers 2015 Diesel Cruze 1G1P75SZ4F7153752 Diagnostics Report, p. 255.

233 Clearing DTCs is a procedure that deletes trouble codes and other electronic information from a vehicle's computer memory. Technicians often use a scan tool to clear DTCs after completing service or repair procedures. On some vehicles, DTCs can also be cleared by unplugging the vehicle's battery for a prolonged duration.

234 Smithers Deposition, Vol. I, 226:24 – 229:6.

mile of the DTCs having being cleared).[235] Unfortunately, Exponent found that due to the DTCs having been cleared, the freeze frame data did not include a record of the initial P21DD fault. Mr. Smithers provided no documentation or other records of this or any other faults.

The true timing of the first P21DD fault occurred more than 20 miles before the multiparty inspection. However, record of the exact time of onset of the P21DD fault was permanently lost due to the Diesel Test Vehicle's DTCs having been cleared. Similarly, it is also possible that the electronic record of other predating troubles codes were permanently lost due to the DTCs being cleared. In other words, it is possible that the Diesel Test Vehicle had other emissions-related faults that occurred during Mr. Smithers' emissions testing, but record of the fault was lost due to the DTCs having been cleared shortly before the inspection.[236] Notably, the multiparty inspection revealed that the DTCs on the Gasoline Test Vehicle used by Mr. Smithers were *not* similarly recently cleared.

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235 Smithers 2015 Diesel Cruze 1G1P75SZ4F7153752 Diagnostics Report, p.254.

236 For example, the DTC clearing process not only caused valuable trouble code and freeze frame information to be permanently lost, but it also caused adaptive values pertaining to the vehicles powertrain and emissions system to reset to their default values. As such, at the time of the multiparty inspection, the parameter values that Exponent would normally value as evidence of the condition of the test vehicle during Mr. Smithers' testing were not necessarily representative of their values before the DTC clearing or during Mr. Smithers' emissions testing. The DTC clearing also caused the status and results of all of the Diesel Test Vehicle's inspection/maintenance system monitor tests to be lost. As such, it is possible that the Diesel Test Vehicle used by Mr. Smithers had additional issues with its emissions system that could not have been identified during the multiparty inspection as a direct result of the DTCs having been cleared.

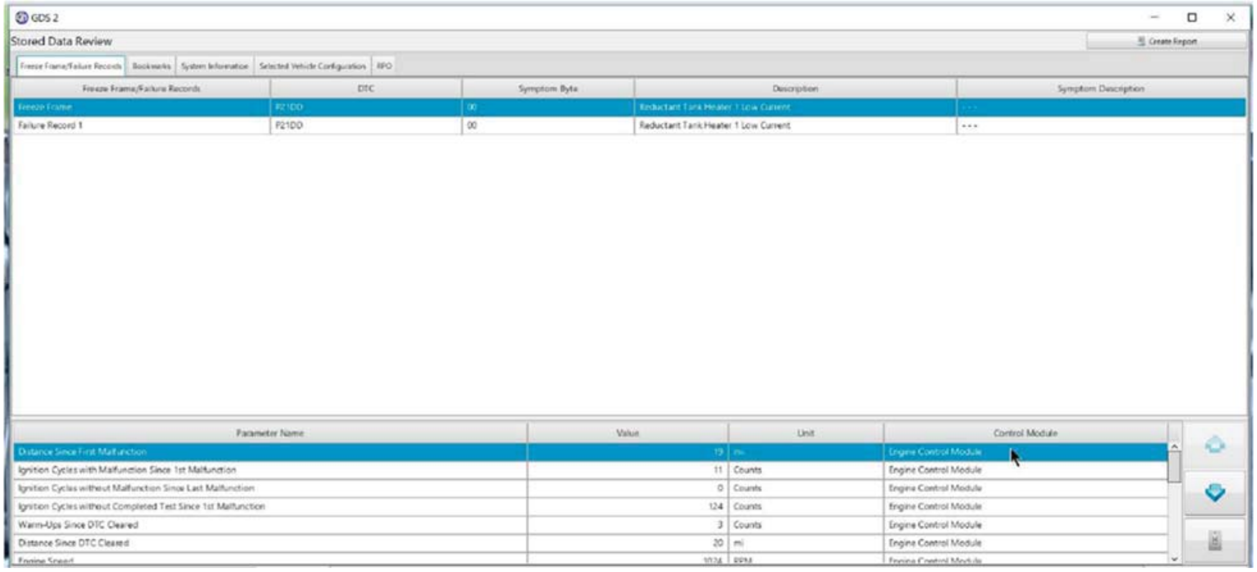

Figure 6-13 Freeze frame data for P21DD (Reductant Tank Heater 1 Low Current) fault stored in Diesel Test Vehicle computer system at the start of the multiparty examination on February 28, 2020.[237] Notice that the distance since first P21DD malfunction was only 19 miles but that the vehicles DTC's were cleared 20 miles prior to the inspection.

According to Halderman's textbook on Automotive Technology: Principles, Diagnosis and Service:

> *"A DTC should not be cleared from the vehicle computer memory unless the fault has been corrected and the technician is so directed by the diagnostic procedure. If the problem that caused the DTC to be set has been corrected, the computer will automatically clear the DTC… The codes can also be erased by using a scan tool."*[238]

In deposition, Mr. Smithers stated that the Diesel Test Vehicle's DTCs were cleared by one of his engineers shortly before the multiparty inspection. He explained, "I think that his goal was to see if it was a spurious code to see if it would come back" and that although he directed the engineer not to clear the code, he did anyway.[239] Considering the fact that the DTC returned immediately, the code was clearly not "spurious," and indeed appears to indicate an issue with the Diesel Test Vehicle. However, by clearing the codes before the inspection, Mr. Smithers' engineer, seemingly without intent, deleted valuable electronic evidence.

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237 Smithers 2015 Diesel Cruze 1G1P75SZ4F7153752 Diagnostics Report, p. 254.

238 Halderman, James D. Automotive Technology: Principles, diagnosis, and service. Prentice Hall, 2009, p. 962.

239 Smithers Deposition, Vol. I, 226:24-228:11.

6.3.1.3.3 Inaccurate Engine Oil Life Indicator

It appears that at the time of the multiparty inspection, the engine oil life indicator displayed on the Diesel Test Vehicle's instrument display was inaccurate. The vehicle's oil life indicator read 98% oil life remaining (see Figure 6-11, above), suggesting that the engine oil was changed shortly before the inspection. However, Exponent has seen no record of the engine oil being changed shortly before the inspection. Furthermore, Exponent collected and tested an oil sample from the Diesel Test Vehicle during the multiparty inspection, and the oil test results indicate that the engine oil was not brand new. Instead, the results indicate that the engine oil had approximately 2.5% fuel dilution and significant oxidation, which is more consistent with used oil, or oil used in an engine with a malfunctioning engine or fuel system, than oil with 98% life remaining in a healthy engine.[240]

The owner's manual for the Diesel Test Vehicle states the following:[241]

> *"This vehicle has a computer system that indicates when to change the engine oil and filter. This is based on a combination of factors which include engine revolutions, engine temperature, and miles driven. Based on driving conditions, the mileage at which an oil change is indicated can vary considerably. For the oil life system to work properly, the system must be reset every time the oil is changed."*
>
> *"Be careful not to reset the oil life display accidentally at any time other than after the oil is changed. It cannot be reset accurately."*

6.3.1.3.4 Failure to Address Upstream NOx Sensor Recall

In May 2017, General Motors issued an emissions recall bulletin which called for the replacement of the upstream NO_x position 1 sensor on the Subject Vehicles, including the Diesel Test Vehicle. The bulletin states:

"General Motors has decided to conduct a Voluntary Emission Recall involving certain 2014 and 2015 model year Chevrolet Cruze model vehicles equipped with a 2.0L (RPO LUZ) diesel engine. On some vehicles, depending on driving habits, soot may build up on the engine's Nox position 1 sensor and / or oxygen sensor, causing the vehicle Check Engine Indicator to illuminate."[242]

Despite the recall bulletin being issued prior to his second and third series of on-road PEMS evaluations conducted between August 2018 and February 2019, Mr. Smithers did not complete the recall applicable to the Diesel Test Vehicle. Rather than replace the NO_x

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240 GMCOUNTS000899749.

241 GMCOUNTS000364835 at GMCOUNTS000365109, GMCOUNTS000365110.

242 General Motors Product Emission Recall N151645630, NO_x Position 1 Sensor Replacement, May 2017. Available at: https://my.gm.com/recalls?vin=1G1P75SZ4F7153752.

position 1 sensor and reprogram (i.e., "reflash") the test vehicle's computer system, Mr. Smithers ignored the recall bulletin and proceeded to perform emissions testing on a vehicle with an open recall. Indeed, during the multiparty inspection, the test vehicle's upstream NO_x position 1 sensor was removed and found to be covered in soot (see Figure 6-14) consistent with the condition described in the recall bulletin that Mr. Smithers failed to address.

Figure 6-14 Photograph of the Diesel Test Vehicle's soot-covered NO_x position 1 sensor.[243]

General Motors advised their dealers of their responsibilities with regards to completing the recall, reporting *"… whenever a vehicle subject to this recall enters your vehicle inventory, or is in your dealership for service in the future, you must take the steps necessary to be sure the recall correction has been made before selling or releasing the vehicle."*[244]

In this statement, General Motors sent a very clear message to their service professionals, that before one of the Subject Vehicles is to be sold or released, the recall repair must be performed. Therefore, not only was it against best servicing practices for Mr. Smithers to ignore the emissions recall bulletin, but it is was critical enough of an act to cause the vehicle to potentially be classified as unfit for sale or release. Indeed, as stated above, Exponent was forced to drive the Diesel Test Vehicle on a private track during the multiparty inspection because it would have been illegal to operate the vehicle on public roads with an open recall. The fact that Mr. Smithers performed emissions testing on the Diesel Test Vehicle without

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243 GMCOUNTS000898910.

244 General Motors Product Emission Recall 17089, NO_x Position 1 Sensor Replacement, May 2018, available at https://static nhtsa.gov/odi/tsbs/2018/MC-10143415-9999.pdf.

performing the necessary repairs pertaining to the recall diminishes the reliability of his test data and further calls into question whether the Diesel Test Vehicle was representative of the Subject Vehicles.

6.3.1.3.5 Outdated Engine Control Software

The aforementioned scan of the Diesel Test Vehicle's computer system conducted as part of the multiparty inspection, identified that the vehicle's engine control software version was outdated and overdue for four updates, as shown in Figure 6-15 below. The uninstalled software updates are emissions-related and include software and diagnostic enhancements pertaining to the performance of an oxygen sensor and a NO_x sensor. The fact that the vehicle's software was found to be outdated is consistent with the NO_x position 1 sensor recall repair—which would have included a computer system reflash—having not been performed (i.e., had Mr. Smithers replaced the NO_x sensor when the recall was issued, the computer system would have undergone a "reflash.")

Regardless, Mr. Smithers' failure to keep the Diesel Test Vehicle's computer software updated is yet another example of improper maintenance practices. Considering the fact that the unapplied updates pertain to the vehicle's emission systems, it is possible that Mr. Smithers' failure to update the Diesel Test Vehicle's software affected the results of his emissions testing.

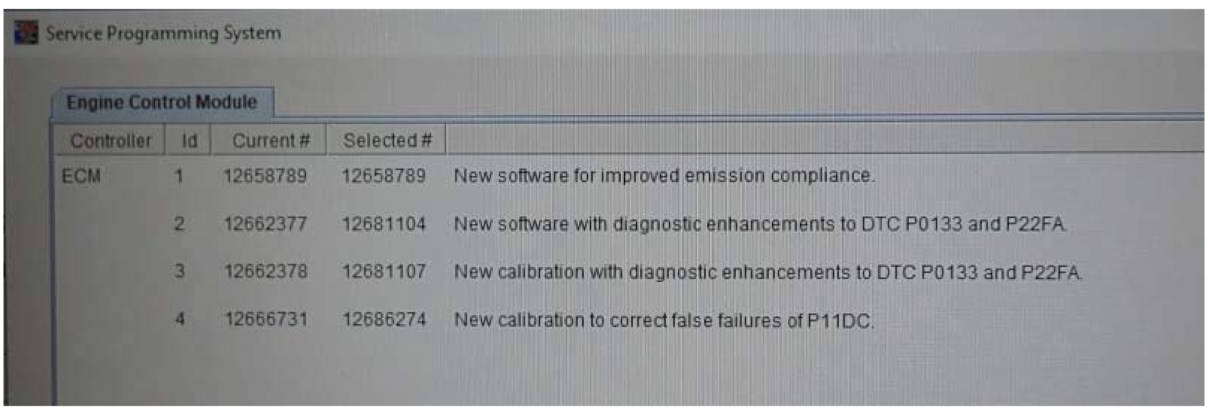

Figure 6-15 Photograph of the Diesel Test Vehicle's outdated engine control module software programming, acquired during the computer scan performed at the February 28, 2020 multiparty inspection.[245]

6.3.1.3.6 Downstream Exhaust Leak Present

During the multiparty inspection, a significant hardware issue was identified with respect to the exhaust system of the Diesel Test Vehicle. The vehicle had an exhaust leak at and around

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[245] GMCOUNTS000898833

the location of the downstream NO_x sensor. (Note that this NO_x sensor is downstream of the SCR catalyst and it is separate from the upstream NO_x position 1 sensor subject to a recall that I described above.) The leak was discovered during a smoke test, a common inspection procedure used to identify leaks. In order to better visualize the leak, soapy water was sprayed around the leak location and, as can be seen in Figure 6-16, large bubbles formed, indicating an exhaust leak in the area of the NO_x sensor threads and bung. An exhaust leak can affect the after-treatment system operation therefore suggesting that, at least at the time of the multiparty inspection, the Diesel Test Vehicle was not fit for emissions testing.

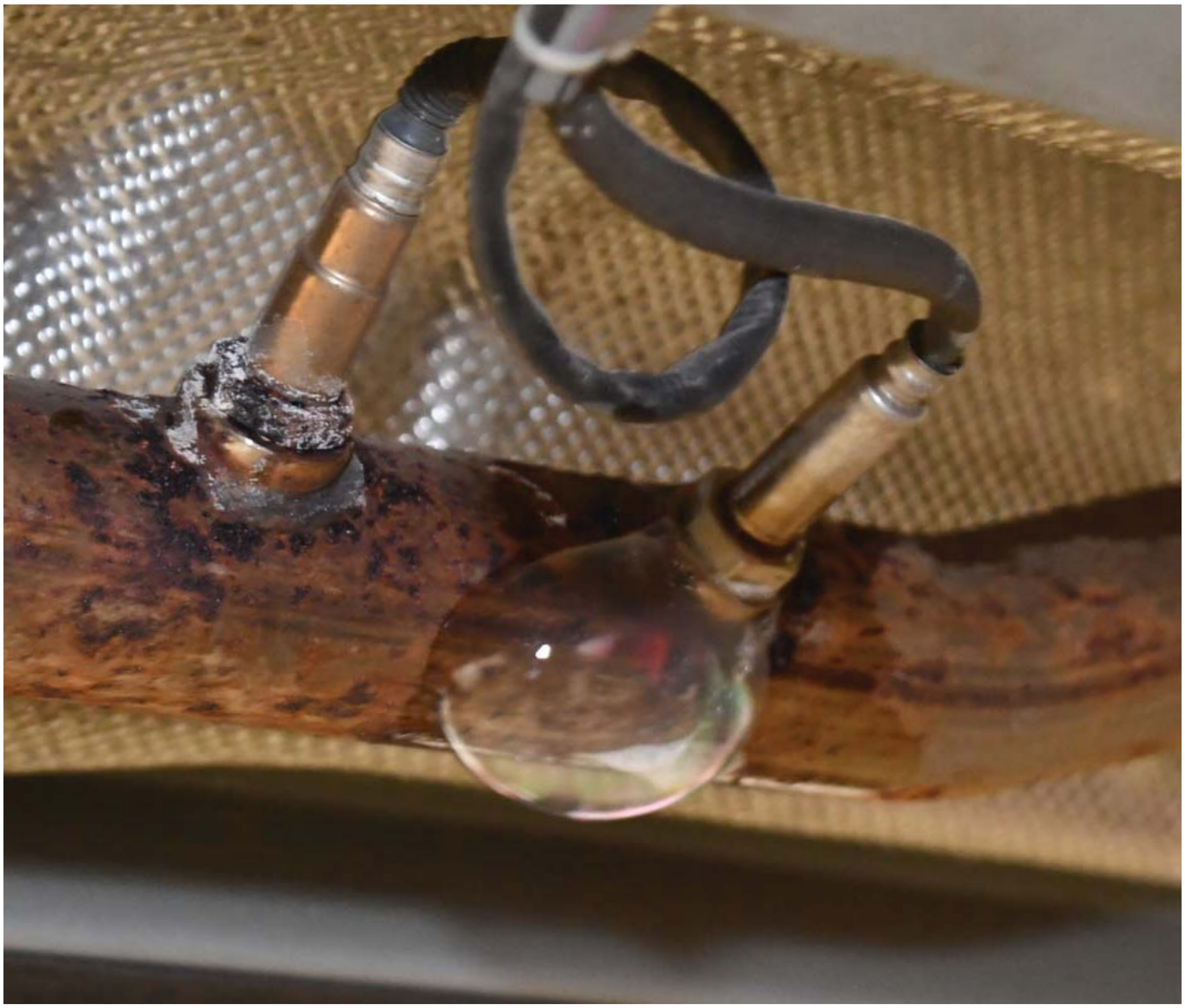

Figure 6-16 Photograph of bubble forming after soapy water was applied during smoke/pressure testing of the Diesel Test Vehicle exhaust system.[246] The large bubble indicates a sizeable exhaust leak at the location of downstream NO_x sensor.

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[246] GMCOUNTS000899149

According to records produced by Mr. Smithers,[247] the downstream NO_x sensor was replaced on March 15, 2018, one day prior to the dynamometer HWFET and Cold FTP tests but one day after he conducted the dynamometer US06 and FTP and before Mr. Smithers' second and third series of on-road PEMS evaluations using the Diesel Test Vehicle, conducted between August 2018 and February 2019. Mr. Smithers stated that he replaced the NO_x sensor at that time because of a MIL that illuminated during the warm-up cycle for one of his dynamometer tests.[248] He provided no documentation or record from a scan tool or the vehicle's computer to show what caused this MIL illumination or when it first arose, and it is possible that the leak predates his downstream NO_x sensor repair. However, the leak is consistent with damage caused, at least in part, by an improperly-performed NO_x sensor replacement. For example, it is possible that the leak started due to the NO_x sensor threads being damaged during the replacement and/or from the replacement NO_x sensor being improperly torqued.[249,250] However, a root-cause analysis to identify the cause of the leak was not performed.

Independent of the cause of the Diesel Test Vehicle exhaust leak, the leak issue has the potential to negatively affect the performance of the vehicle's exhaust after-treatment system. Exhaust leaks are known to be capable—depending on leak size, location, vehicle operating conditions and other factors—of allowing undesirable air to be entrained into, and exhaust to be expelled out of, the exhaust system, in a manner that can negatively affect the accuracy of sensors (e.g. the downstream NO_x sensor and the PEMS unit) and be detrimental to exhaust after-treatment component performance. The size of exhaust leaks, and their impact on vehicle performance, can change in a complex manner with time and conditions. Exponent has seen no record of Mr. Smithers ever checking or testing the exhaust system of his test vehicle for leaks and Mr. Smithers testified that he never conducted an exhaust leak test.[251] Therefore, the extent of the impact that the Diesel Test Vehicle exhaust leak had on Mr. Smithers' test data may never be determinable.

Regardless, the fact that the Diesel Test Vehicle had an exhaust leak around the downstream NO_x sensor which may have affected the vehicle's performance, including its NO_x emissions, diminishes the reliability of his emissions test data. Moreover, the presence of this exhaust leak on the Diesel Test Vehicle renders it non-representative of other vehicles included in the

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247 "Cruze Vehicle Modification Summary.xlsx" document produced by Mr. Smithers, which outlines modifications made to the Diesel Test Vehicle.

248 Smithers Deposition, Vol. I., 189:11-190:8.

249 Smithers Deposition, Vol. I, 226:24 - 229:6.

250 Mr. Smithers testified that a member of his staff replaced the sensor and that "It's a simple replacement. You unscrew it. You screw the new one in. You click the harness in. It's -- you don't need any special training to do it." Smithers Deposition, Vol. I, 190:18-191:17.

251 Smithers Deposition, Vol. I, 213:14-19.

Plaintiffs' proposed class. The EPA requires manufacturers to submit a description and justification related to their leak-free exhaust system design.[252]

6.3.1.4 Conclusion Regarding the Representativeness of the Diesel Test Vehicle

Considering the many issues identified during the multiparty inspection pertaining to the Diesel Test Vehicle, including an illuminated check engine light, multiple fault codes stored in the vehicles computer system and never documented by Mr. Smithers, an exhaust leak, an unaddressed recall, outdated software, and cleared DTCs, I conclude that the test data that Mr. Smithers collected during his emissions tests is unreliable. As a consequence, the conclusions that Mr. Smithers draws based on testing the Diesel Test Vehicle are unreliable.

Despite an open recall, no maintenance history, and an FTP dynamometer test that indicated anomalies with the Diesel Test Vehicle's NO_x emissions, Mr. Smithers continued to collect PEMS data. Between August of 2018 and February of 2019, he conducted a second and third series of on-road evaluations accounting for approximately 6,000 miles worth of driving (or approximately 85% of the total PEMS testing mileage on the Diesel Test Vehicle that he used for his analysis). Furthermore, information produced after Mr. Smithers' report revealed that a downstream NO_x sensor was replaced part-way through his testing without any assessment of the impact of this replacement, or verification that the emissions system was in good working condition prior to or after the repair. At the time of Exponent's vehicle inspection, a significant exhaust leak was found at the location of this NO_x sensor, and it was also found that the vehicle's fault code data had been erased.

As shown by the in-use data produced by GM, maintenance issues can affect the after-treatment system's performance, particularly in diesel vehicles that adopt sophisticated emissions control strategies as in the Subject Vehicles. When Mr. Smithers noted that the Diesel Test Vehicle was producing higher than expected levels of NO_x on the FTP, he should have investigated the root cause and ensured that all of the vehicle's systems (including, in particular, the after-treatment systems) were operating as intended. If the replacement of the downstream NO_x sensor was performed to correct for this high FTP measurement, Mr. Smithers should, at a minimum, have verified the impact of the replacement by running the FTP test again after the downstream NO_x sensor was replaced. Instead, Mr. Smithers continued to conduct PEMS evaluations for thousands of miles on a vehicle that likely suffered from emissions after-treatment system abnormalities, and he then made conclusions regarding all Subject Vehicles based primarily on his testing of that one unrepresentative vehicle.

The timeline in Figure 6-8 above also shows that Mr. Smithers collected PEMS data both before and after the dynamometer runs conducted on the Diesel Test Vehicle, and therefore

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252 Code of Federal Regulations, Part 86, Section 1844-1, available at https://www.govinfo.gov/content/pkg/CFR-2012-title40-vol20/pdf/CFR-2012-title40-vol20-sec86-1844-01.pdf

he had the appropriate equipment to evaluate the correlation between the readings of his PEMS setup against calibrated lab equipment, but failed to do so. Such an exercise is basic scientific and engineering practice and it was followed by the West Virginia CAFEE study on in-use emissions[253], and required by the European real driving emissions (RDE) regulations[254] and the EPA and CARB heavy duty in-use compliance program,[255] all of which Mr. Smithers referenced in his own report.[256]

In summation, Mr. Smithers failed to produce records indicating proper regular maintenance on the Diesel Test Vehicle after purchasing it and continued to test the vehicle even though it was subject to an open recall pertaining to an upstream NO_x sensor. Further, he continued to perform PEMS testing and failed to confirm that the exhaust after-treatment system was functioning as designed after learning that the Diesel Test Vehicle was producing NO_x at levels that did not conform to FTP dynamometer emissions standards. As such, the results of Mr. Smithers' PEMS testing are questionable as to their applicability beyond the specific, tested vehicle in its current state of repair, and cannot be considered representative of the population of Subject Vehicles, and do not reliably support Mr. Smithers' broad opinions regarding the Subject Vehicles including Mr. Smithers' defeat device allegations that I discuss further in Section 7 .

6.4 Mr. Smithers' Driving Did Not Reflect "Typical" Driving Conditions and His Data Analysis is Based on Faulty Assumptions and Deceptive Data Presentation

In addition to limitations discussed so far related to PEMS testing and the representativeness of the Diesel Test Vehicle, there are several issues with the way in which Mr. Smithers reviewed, analyzed, and interpreted the PEMS data that he collected on the Diesel Test Vehicle. While Mr. Smithers claimed to have controlled and monitored his PEMS testing routes for variations in test conditions, which he suggested "allows for a direct comparison to the standards," there are many important and influential variations in his test conditions that he overlooked, ignored, or failed to adequately address in his data analysis.[257] While the sections below provide a detailed description of the shortcomings of Mr. Smithers' approach, the main limitations with his approach includes an overrepresentation of extreme temperature conditions (as described in Section 6.2.4), a faulty road grade analysis, a biased data

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253 Thompson, Gregory J. et al., "In-Use Emissions Testing of Light-Duty Diesel Vehicles in the United States," Prepared for: International Council on Clean Transportation (ICCT), May 2014.

254 PEMS validation procedures require that PEMS are validated against laboratory CVS equipment and that NO_x measurements are within "± 15 mg/km [24 mg/mi] or 15 % of the laboratory reference, whichever is larger." COMMISSION REGULATION (EU) 2016/427 of 10 March 2016 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6). March 31, 2016.

255 40 CFR § 1065.920 - PEMS calibrations and verifications.

256 Smithers Report, ¶ 83.

257 Smithers Report, ¶ 111.

segmentation methodology, and a lack of proper contextualization of Mr. Smithers' emissions results.

6.4.1 Mr. Smithers' Evaluation of Road Grade Relies on Faulty Assumptions and Data Analysis Methods

Mr. Smithers' testing of the Diesel Test Vehicle included a variety of driving conditions including roads with varying elevation profiles. As discussed in Appendix E, while all of the EPA's certification driving schedules, test protocols, and emissions standards assume a flat road grade, it is expected that in the real world, a vehicle will encounter conditions where the road grade is non-zero. In that sense, Mr. Smithers' inclusion of segments with elevation change is not unexpected. However, Mr. Smithers' failure to appropriately acknowledge the impact of road grade on emissions and his analysis of road grade is flawed for three fundamental reasons:

1. It is well known that NO_x emissions increase when road grade increases.[258] In his report, Mr. Smithers presented data showing the correlation between road grade and NO_x emissions,[259] yet he did not consider it appropriately in his analysis of the data that he collected.
2. Mr. Smithers' segmentation approach did not capture road grade in a meaningful way, providing the false impression that many test segments associated with his driving of the Diesel Test Vehicle were "flat".
3. Mr. Smithers' analysis regarding the prevalence of road grade in the real world is flawed when actual driving behavior is considered.

First, because NO_x emissions are known to increase with road grade, increased NO_x emissions for segments with higher road grade are to be expected. For instance, the European Commission RDE protocol applicable to on-road testing has specific provisions for cumulative elevation gain and for driving at elevation.[260] These provisions include:

- Total positive elevation gain is to be less than 1,200 meters (3,937 ft) over 100 kilometers (62 mi);
- Altitude difference between start and stop is to be less than 100 meters (328 ft) (i.e., one cannot start at the bottom of a mountain and end the test at the top, or vice versa);

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258 *See e.g.*, "FAQ: In-use NOx emissions from diesel passenger cars." The International Council on Clean Transportation. Available at: http://www.theicct.org/news/faq-use-nox-emissions-diesel-passenger-cars. Accessed, June 5, 2020.

259 *See e.g.*, Smithers Report, Table 9-3, p. 45.

260 It should be noted that also the EPA heavy-duty PEMS protocols have limitations on max altitude.

- Emissions data collected between 700 meters (2,297 ft) and 1,300 meters (4,265 ft) of elevation need to be adjusted downward by a 1.6 scaling factor; and
- Exceeding 1,300 meters (4,265) of elevation during the drive invalidates the test.[261]

Mr. Smithers' test routes and segments included a much wider set of elevation conditions than those allowed under the European Commission RDE protocol. For example, he tested routes with segments above 2,500 meters (8,202 ft),[262] as well as a route with a start to finish elevation change in the order of 2,000 meters (6,562 ft).[263] Yet, he did not try to apply any correction factor to his data, nor even attempt to contextualize his results.

Second, even for segments that Mr. Smithers considered "flat," there are often significant elevation changes that were overlooked by Mr. Smithers' route segmentation and overly-simplistic approach to elevation grade calculation. Mr. Smithers calculated average road grade as the difference in elevation between the start and stop location of each segment (i.e., the net grade traveled over the entire segment driven). As a result, if a segment started and ended at the same elevation, but went through a series of rolling hills, Mr. Smithers' analysis would consider it a flat segment, which is misleading. As seen in the European RDE protocol requirements introduced above, it is important to look not only at the difference in altitude between the start and stop location but also the elevation gain *during* the ride (i.e., how many vertical feet are climbed during the course of the ride). An analysis of the segments that Mr. Smithers classified as "flat"[264] reveals that out of the approximately 5,400 miles along the supposedly flat segments on the Diesel Test Vehicle, approximately 1,950 miles were actually driven uphill at an average-per-segment positive grade of 1.4% and approximately 1950 miles were driven downhill at an average grade of -1.3%.[265] This indicates that even during segments reported as "flat" by Mr. Smithers, there was often elevation change that

261 See Commission Regulation (EU) 2016/427, available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32016R0427. Commission Regulation (EU) 2016/646, available https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016R0646.

262 *See* e.g., Route ID 4-19-20, Seconds 0-650.

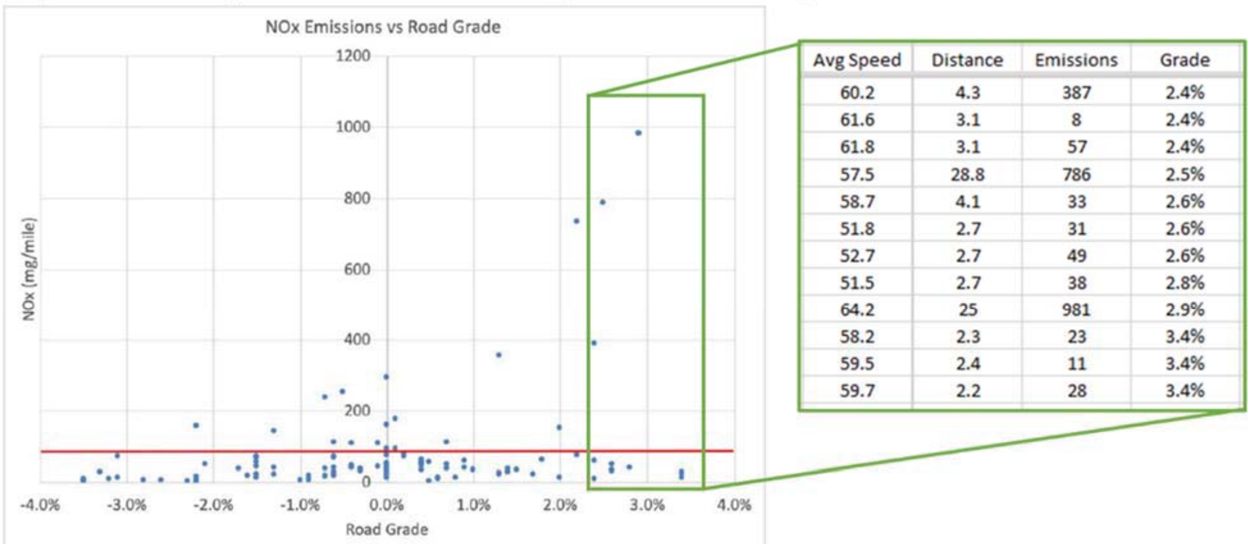
263 *See* e.g., Route ID 19-11-30

264 Mr. Smithers classifies a segment as flat if the average grade is between -0.3% and +0.3%. *See* Smithers Report ¶ 111, footnote 35.

265 Mr. Smithers' instantaneous data was analyzed to calculate the vertical distance climbed and for each segment. Then the average uphill grade for the portion of the ride driven on upslope was calculated. For example, a hypothetical segment 20 miles long can be flat according to Mr. Smithers's metric if the start and stop locations are at the same elevation. However, if during the first 10 miles of this hypothetical segment the road goes up 1 mile (i.e., 1 mile of elevation) and then during the last 10 miles the route continues back to the original elevation, the average uphill grade for that segment will be 10% (1 mile of elevation / 10 miles driven x 100). The average-per-segment positive grade is the average positive grade of each segment. For example, if a segment of 10 miles has a 5% average uphill grade and a segment of 20 miles has a 3% average uphill grade, the average-per-segment positive grade will be 4%.

likely increased NO_x emissions.[266] However, by using his flawed approach for evaluating road grade, Mr. Smithers failed to consider this factor in his evaluation of emissions from the Diesel Test Vehicle.[267]

Third, Mr. Smithers' discussion of road grade in the real world is overly simplistic and he drew erroneous interpretations from his own testing data. When comparing NO_x emissions from the Diesel Test Vehicle against road grade in Figures 9-13 and 9-14 of his report, Mr. Smithers reported that "the data points with low emissions at higher road grades are for test segments with a short duration."[268] With this statement, Mr. Smithers tried to dismiss data points that show NO_x emissions associated with the Diesel Test Vehicle below 90 mg/mi as outliers. However, as shown in Figure 6-17 below, these segments are not of insignificant length, ranging from 2.2 miles to 4.1 miles, which do in fact reflect driving conditions and lengths more likely to be encountered during real-world driving as demonstrated below.



Avg Speed	Distance	Emissions	Grade
60.2	4.3	387	2.4%
61.6	3.1	8	2.4%
61.8	3.1	57	2.4%
57.5	28.8	786	2.5%
58.7	4.1	33	2.6%
51.8	2.7	31	2.6%
52.7	2.7	49	2.6%
51.5	2.7	38	2.8%
64.2	25	981	2.9%
58.2	2.3	23	3.4%
59.5	2.4	11	3.4%
59.7	2.2	28	3.4%

Figure 9-13: 2015 Cruze diesel NOx emissions as a function of road grade in steady highway conditions, speeds of 65 mph and lower.

Figure 6-17 Mr. Smithers' Figure 9-13 and an excerpt of Mr. Smithers' data from "PEMS Overall Summary Cruze for Final Report.xlsx" showing additional properties of the underlying data used to generate the figure.

266 The engine is still running even though no motive power may be needed on downhill portions, and the after-treatment system can cool making it less effective, which can lead to higher NO_x emissions. A segment with zero start-to-finish grade but non-zero average uphill grade can have increased NO_x as the downhill portions of the segment don't simply negate the increased NO_x on the uphill portions.

267 Additionally, Mr. Smithers' highway segments for this analysis included average speeds greater than the maximum speed attained on the HWFET cycle, which further biases his road grade analysis when comparing to the HWFET standard.

268 Smithers Report, ¶¶ 125, 126.

It is important to note that Mr. Smithers cited data from the National Renewable Energy Laboratory (NREL)[269] on road grades on controlled access highways in the U.S. to justify the relevance of his findings related to the Cruze diesel performance on sloped roadways.[270] Mr. Smithers reported NREL statistics that show that 10% of U.S. controlled access highways mileage have an absolute road grade above 3%.[271] This information is of no value in the context of typical driving conditions as it does not capture how many miles US drivers actually drive on these highway portions with high road grade.[272]

Moreover, Mr. Smithers overlooked the fact that the NREL research paper that he cited also included an analysis of the "half hill" length distribution. In the paper, a "half hill…was defined as a continuous stretch of roadway where grade does not change sign (i.e., sections of exclusive climb or descent)."[273] Figure 6-18 below, shows the half-hill distributions by raw half-hill frequency (solid line) and roadway distance (dashed line) for U.S. highways as calculated by NREL.[274] It shows that approximately 90% of the individual half-hills are less than 1.1 miles long, while approximately 90% of total highway road miles are along half-hills less than 3 miles long. This reinforces the fact that Mr. Smithers selectively highlighted atypically long segments at positive grade in his discussion of the influence of road grade and emissions in his report, while neglecting segments that are more representative of commonly encountered road grades. Indeed, Mr. Smithers' own data and cited literature actually shows that the Cruze diesel would not have elevated NO_x emissions for the vast majority of highway driving with road grade.

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269 Wood, Eric, et al. "EPA GHG Certification of Medium- and Heavy-Duty Vehicles: Development of Road Grade Profiles Representative of US Controlled Access Highways," NREL Study under Contract DE-AC36-08GO28308, May 2015.

270 Smithers Report, ¶ 129.

271 Smithers Report, ¶ 130.

272 Mr. Smithers testified that he had not consulted data about driving time on roads with grade above 2.0 percent. Smithers Deposition, Vol. II, 410:9-22.

273 Wood, Eric, et al. "EPA GHG Certification of Medium- and Heavy-Duty Vehicles: Development of Road Grade Profiles Representative of US Controlled Access Highways," NREL Study under Contract DE-AC36-08GO28308, May 2015. *See* p. 17.

274 Wood, Eric, et al. "EPA GHG Certification of Medium- and Heavy-Duty Vehicles: Development of Road Grade Profiles Representative of US Controlled Access Highways," NREL Study under Contract DE-AC36-08GO28308, May 2015. *See* p. 19.

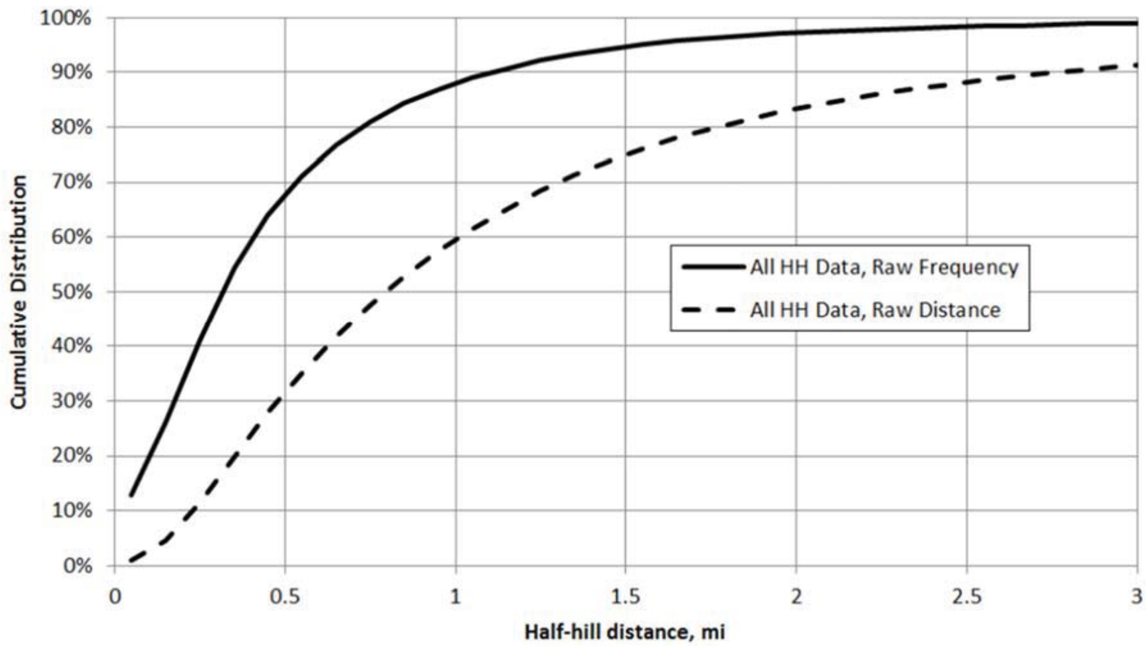

Figure 6-18 Half-hill distance and frequency distribution for U.S. highways.[275]

6.4.2 Mr. Smithers' Data Segmentation Misrepresents Vehicle Emissions

As I describe in further detail below, the data analysis methodology employed by Mr. Smithers on the PEMS data generated by his on-road driving of the Diesel Test Vehicle was not consistent with good scientific practices. Mr. Smithers' route segmentation methodology was not well defined, was not consistently applied, and for some analyses it biased the data to imply that the Diesel Test Vehicle operated more frequently on-road above the dynamometer certification test cycle standards.

6.4.2.1 Evaluation of Speed and RPA Shows Meaningful Differences between Mr. Smithers' Driving of the Diesel Test Vehicle and the EPA Test Cycle Protocols and Associated Emissions Standards

Mr. Smithers divided his PEMS testing data for the Diesel Test Vehicle into two categories: city driving (i.e., stop-and-go) and highway driving. He also took each of the test routes that he drove and divided them up into arbitrarily-defined smaller test segments. Although Mr. Smithers claimed to have identified test segments based on certain changes in driving conditions, he did not produce a protocol or procedure by which this process could be replicated.[276] In aggregate, Mr. Smithers reported that he tested the vehicle "over the course

275 Wood, Eric, et al. "EPA GHG Certification of Medium- and Heavy-Duty Vehicles: Development of Road Grade Profiles Representative of US Controlled Access Highways," NREL Study under Contract DE-AC36-08GO28308, May 2015. *See* p. 19.

276 Smithers Deposition, Vol. II, 309:4-311:20.

of 1,825 miles and 278 test segments in city driving conditions," and "over 6,236 miles and 403 test segments in steady highway driving conditions."[277] Additionally, he stated "[t]he vehicle was tested over the FTP-75, HWFET, and Cold CO cycles, as the PEMS testing was designed primarily to mirror speed and acceleration conditions of those tests."[278] However, as discussed above and will be discussed further below, there were significant differences between his on-road PEMS testing and the standardized dynamometer cycles.

To evaluate the driving style during his on-road testing, Mr. Smithers calculated the "relative positive acceleration" (RPA) for each of his test segments and compared it to the RPA of the FTP, the US06, and the HWFET test cycles.[279] RPA is a metric that captures the frequency and intensity of positive acceleration (i.e., it excludes braking) levels during a drive. For example, cruising at 60 mph on the highway has an RPA close to zero.[280]

Figure 6-19 presents the RPA for all of the segments considered by Mr. Smithers and compares it to the RPA of the applicable test cycle (FTP for city driving, US06 and HWFET for highway driving). For the city driving, data shows that Mr. Smithers' driving of the Diesel Test Vehicle, in terms of speed and acceleration as measured by the RPA, was generally similar to the FTP test cycle conditions (left panel of Figure 6-19). However, as acknowledged by Mr. Smithers, the average speed during the city segments was 25.5 mph, while the average speed during FTP cycle is 21.2 mph.[281] This discrepancy, although understandable in the context of on-road driving, demonstrates the inherent challenges of reproducing the conditions encountered during certification test cycles in on-road testing.

On highway segments however, the RPA data show that Mr. Smithers' driving of the Diesel Test Vehicle was significantly and consistently different from the US06 and the HWFET test cycles, as measured both by speed and RPA (right panel of Figure 6-19). Even though the average speed during the HWFET is 48.3 mph, Mr. Smithers stated that "Highway testing was generally conducted at a steady speed of 60 mph, though certain test segments cover higher speed. Testing was conducted in this way as a surrogate for the HWFET test cycle."[282] The data, however, clearly show that Mr. Smithers consistently drove the Diesel Test Vehicle at speeds *higher* than both the HWFET and US06 average speed, and the distribution of the RPA during Mr. Smithers' highway segments did not reflect the aggressiveness of actual HWFET or US06 test cycles. Moreover, in several analyses where Mr. Smithers' compared seemingly benign "steady speed" highway driving, he included segments with average

277 Smithers Report, ¶¶ 105, 108.

278 Smithers Report, ¶ 81.

279 Smithers Report, ¶¶ 97-104.

280 *See* Thompson Gregory. J. et al., "In-Use Emissions Testing of Light-Duty Diesel Vehicles in the United States," Prepared for: International Council on Clean Transportation (ICCT), May 2014, p. 26.

281 Smithers Report, ¶ 98.

282 Smithers Report, ¶ 101.

speeds up to 65 mph even though the HWFET only includes speeds up to 60 mph and has an average speed of 48.3 mph.

Mr. Smithers asserted that he believes that 60 mph was "a reasonable surrogate for the HWFET cycle," despite differences in acceleration events (as measured by the RPA) and the speed range in the actual HWFET test cycle.[283] This reasoning is without basis and inherently flawed. Mr. Smithers' own PEMS data for the Diesel Test Vehicle have clearly shown that the relationship between diesel NO_x emissions and driving conditions is complex. Therefore, Mr. Smithers cannot reliably assume that driving faster but with fewer or less aggressive accelerations will result in the same load and performance of the engine and after-treatment system, including the resulting NO_x emissions. Therefore, by testing at higher speeds, Mr. Smithers was exercising the emissions control system of the Diesel Test Vehicle in a regime that is more challenging to the emissions control system (i.e., Mr. Smithers was testing the vehicle in conditions that were known to result in higher NO_x emissions). Moreover, while it is generally inappropriate to compare on-road PEMS data to regulatory emissions standards that apply to dynamometer testing, this comparison becomes even less meaningful when the on-road conditions are significantly different from the laboratory test conditions, as was the case with Mr. Smithers' testing of the Diesel Test Vehicle.

Additionally, in justifying the conditions associated with his highway driving of the Diesel Test Vehicle, Mr. Smithers stated:

> *[f]urthermore, steady state vehicle operation represents an ideal condition for an emission control system since no variables are changing. In that case, emission controls are expected to be more efficient than in conditions where vehicle speed and load are constantly changing. In the United States, highway speed limits range between 55 mph and 80 mph and 60 mph is viewed to be conservatively low from an emission control standpoint, where drag forces are relatively low and the engine is not under a particularly heavy load.*[284]

Mr. Smithers seems to imply that his 60 mph "steady state" (i.e., low speed variations) testing is an ideal and/or conservative testing approach from an emissions perspective. If this were true, one would expect to see fuel economy measurements for Mr. Smithers' highway driving of the Diesel Test Vehicle *better than* those reported in the results of the HWFET test cycle conducted as part of the Subject Vehicles' certification process. However, Mr. Smithers' highway on-road testing resulted in fuel economy measurements approximately 10% *lower* than the HWFET test cycle, indicating that there were higher loads on the engine

283 Smithers Report, ¶ 101.

284 Smithers Report, ¶ 102.

during Mr. Smithers' PEMS testing, which would be expected to result in increased emissions.[285]

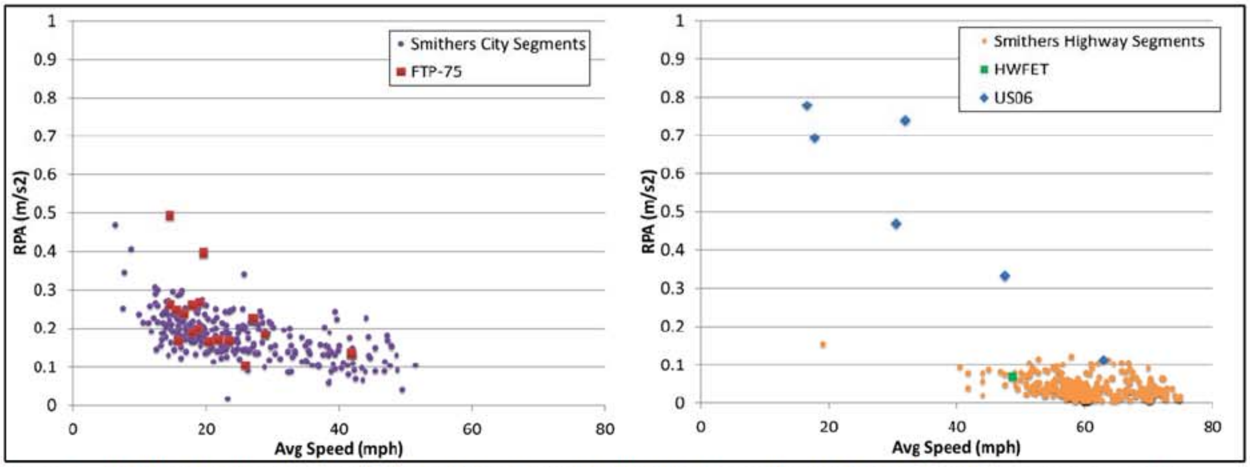

Figure 6-19 RPA distribution for the Diesel Test Vehicle PEMS data collected by Mr. Smithers as compared to FTP, US06, and HWFET test cycles. City (i.e., stop-and-go) segments on the left, and highway segments on the right.

6.4.2.2 Mr. Smithers' Arbitrary Route Segmentation is Flawed and Misleading

As described above, Mr. Smithers divided his testing data for the Diesel Test Vehicle into city driving (i.e., stop-and-go) and highway driving. He also took each of the test routes that he drove and divided them up into arbitrarily-defined smaller test segments. Notably and without discussion or explanation, Mr. Smithers used different segment lengths between the analysis for the Diesel Test Vehicle and the Gasoline Test Vehicle (which had an average segment length 38% longer). As discussed below, segment length can impact the analysis results and render them unreliable.

In attempting to explain how the data was segmented, Mr. Smithers stated that "[i]n general, any individual data point is constrained to have a length of greater than 3.6 miles, which is the length of the shortest phase of the FTP-75 (Phases 1 and 3). Emissions over very short periods of driving can often be very high (for example a 10-second sharp acceleration), so results are averaged over longer distances so the data isn't biased toward very short-term transient events with high emissions."[286] Later Mr. Smithers testified that segments were identified by driving conditions: "so that when a change in condition would come, that would

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285 *See* Smithers Report, ¶ 102 ("Indeed, in the ambient temperature range from 68°F to 86°F, which is the window for the HWFET emissions test, fuel economy is measured to be 53.6 mpg on flat roads. This [PEMS reported] fuel economy is only about 10% lower than the fuel economy presented in the certification application on the HWFET, 59.8 mpg. This is a further indication that engine loads between the PEMS highway testing is comparable to engine load on the HWFET.").

286 Smithers Report, ¶ 98.

generate a new segment."[287] These high-level explanations and the lack of documentation related to a protocol for his segmentation make it impossible to assess the validity of his segmentation methodology.

As an initial matter, Mr. Smithers failed to follow his own stated intention, as 125 of the 680 unique segments selected by Mr. Smithers were 3.5 miles or shorter.[288] Regardless, in actuality, rigidly presenting data derived from either short or long data segments can be equally misleading. It is therefore critical in any sound engineering analysis to consider the underlying emissions data, the context of measured emissions (e.g., the effect of DPF regeneration events which are known to substantially increase NO_x emissions, any extreme environmental conditions, etc.), and the totality of emissions data, which Mr. Smithers failed to do.

The ways in which Mr. Smithers' arbitrarily-defined segmentation lead to biased and misleading representations of his testing data can be illustrated through example. I extracted data from the file produced by Mr. Smithers for a drive that took place on May 25, 2016 (Mr. Smithers Route ID 19-56-23 under the name of "Drive from Oakland to SoCal"). The fourth segment of this test route (taking place from 520 seconds to 911 seconds of the test route), which is a city drive segment, had a distance of 5.2 miles and total reported NO_x emissions of 0.38 g, which yields an average emission of 0.073 g/mi for that segment (i.e., 0.38 g of NO_x divided by 5.2 miles driven). The top panel in Figure 6-20 shows the instantaneous NO_x production reported in Mr. Smithers' data for this segment, showing that tailpipe NO_x instantaneous emissions stayed low for most of this test segment, except for a single spike occurring between 3.5 and 4 miles. Because Mr. Smithers defined this sequence as a single test segment, according to his analysis, the Diesel Test Vehicle was reported to be above the FTP standard of 0.07 g/mile for the entire 5.2 mile segment. However, if these same data were instead segmented in one-mile increments (as an example), only a single one-mile segment would have been above 0.07 g/mi, while the rest of the drive would have been well below (see Figure 6-20, bottom panel). In other words, Mr. Smithers' segmentation concluded that NO_x emissions exceeded the FTP standard for the entire 5.2 mile segment, while an alternate segmentation methodology would conclude that emissions exceeded the FTP standard for only a fraction of the route.

287 Smithers Deposition, Vol. II, 310:4-15.

288 Mr. Smithers selected 680 unique segments, of which one was classified as both stop-and-go (i.e., city) and highway. Segments were ranked by distance and the segments measuring 3.5 miles or less were then counted.

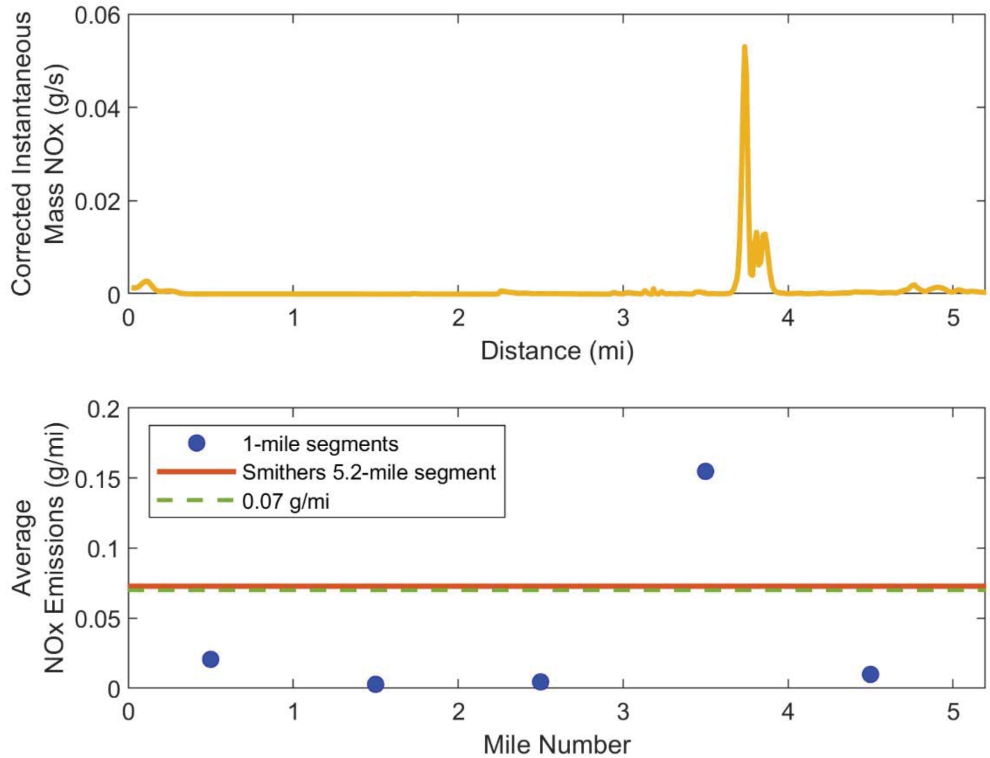

Figure 6-20 Instantaneous NOx emissions in (g/s) during a 5.2 mile long test segment in Mr. Smithers' city data for the Diesel Test Vehicle (top). The bottom chart shows the average NOx emissions in (g/mi) for 1-mile segments (blue dots) and for the entire 5.2 mile segment (i.e., Mr. Smithers' calculated average, green line).

Mr. Smithers compounds his misleading analysis of individual segments by representing the overall PEMS data in a way that duplicates the same data points in multiple columns of the same chart, thus embellishing the number of vehicle miles traveled above FTP and HWFET emissions limits. The left panel in Figure 6-21 below is a reproduction of Figure 9-1 from Mr. Smithers' report. In Mr. Smithers' presentation, the first and second bars from the left represent the percentage of miles of city driving with NO_x below and above 0.07 g/mi, respectively, thus summing up to a total of 100% of the PEMS data. However, the third bar is a subset of the second bar, showing the cumulative percentage of miles with emissions two times and higher than that of 0.07 g/mi value. In other words, this bar includes the percentage of miles with two times, three times, four times etc. the standard emissions values (i.e., Mr. Smithers has double-counted). Hence, the summation of all these bar values greatly exceeds 100%, since each bar value includes repetitive mileage from other bars.

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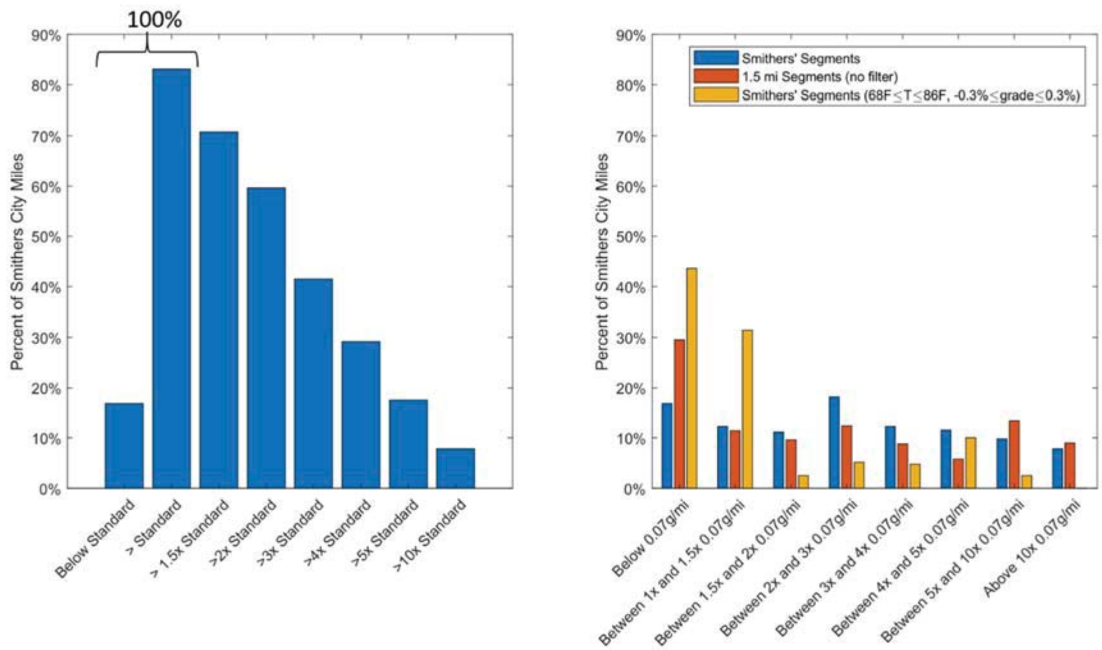

Figure 6-21 (Left) Plot reproduced from the report of Mr. Smithers shows the fraction of city drive miles traveled by Diesel Test Vehicle at various multiples of the FTP standard (0.07 g/mi). (Right) My analysis of the same city-drive segments but presented in a histogram plot. In this representation, the sum of all percentage values equals 100%, as opposed to Mr. Smithers' plot in which the sum is well above 100%.

To illustrate the extent to which Mr. Smithers' double-counting leads to embellished results, I reorganized Mr. Smithers' Figure 9-1 by binning the data behind his chart into unique intervals, instead of showing the data points exceeding arbitrary thresholds as Mr. Smithers did. In this way, the sum of all the bars is 100% and the same data is only accounted for once in the plot. The results of this analysis are shown as the blue bars in the right panel of Figure 6-21.

Of note, this representation is still based on Mr. Smithers' arbitrary segmentation, which may overstate the number of vehicle miles traveled by the Diesel Test Vehicle at a given emissions level, as discussed above. Furthermore, Mr. Smithers also included segments that had active DPF regenerations in this figure. Therefore, some of the bars that account for mileage above the 0.07 g/mi FTP emissions standard are irrelevant because DPF regeneration is an expected and known intermittent behavior of diesel vehicles and should be considered in the context of the entire period of vehicle operation between two regenerations. Finally, and perhaps most importantly, Mr. Smithers' representation also includes ambient temperatures and road grades that are not represented in FTP testing conditions, so any comparison of his PEMS results to the FTP-75 emissions limit (which strictly controls the ambient temperatures and has zero road grade) has little value.

To demonstrate these other limitations of Mr. Smithers' representation of the PEMS data, I also conducted two additional analyses shown in Figure 6-21 by: (1) re-segmenting Mr.

Smithers' data to use 1.5 mile constant segment length (orange bars in Figure 6-21) and (2) using Mr. Smithers' segments but excluding all data that was outside of FTP testing conditions in terms of temperature or road grade[289] (yellow bars in Figure 6-21). The first analysis (orange bars) clearly shows that the chosen segment length affects how the data is distributed. Using 1.5 mile segments, almost 30% of the city vehicle miles driven by the Diesel Test Vehicle produced less than 0.07 g/mi in NO_x emissions, compared to less than 20% when calculated using Mr. Smithers' arbitrary segment lengths; approximately 40% of the city vehicle miles are within 1.5 times 0.07 g/mi, using this uniform segment length. Again, this result should be evaluated keeping in mind that these miles include the extreme temperature conditions and uphill driving discussed in the previous sections.

The second analysis (yellow bars), which retains Mr. Smithers' arbitrary segments, shows the distribution of emissions results when including only those PEMS test segments conducted under conditions nominally similar to the FTP cycle (i.e. within the same ambient temperature range, and with a road grade that Mr. Smithers considers "flat"). Using this approach, *approximately 75%* of the city miles driven by the Diesel Test Vehicle under conditions similar to the FTP resulted in NO_x emissions within 1.5 times the 0.07 g/mi standard (i.e., 0.105 g/mi). With the understanding that there is no regulatory limit for PEMS data, [redacted] consistent with the expectations for on-road performance, and unsurprising given that the Diesel Test Vehicle reported NO_x emissions of 0.078g/mi on the dynamometer while running the FTP test cycle.[292]

I conducted this same set of analyses on the set of data included in Mr. Smithers' Figure 9-4, which compared on-road NO_x emissions from the Diesel Test Vehicle during highway driving to the 0.09 g/mi standard associated with the HWFET test cycle. Figure 6-22 presents the original plot made by Mr. Smithers (left panel) and the set of data analysis I conducted of the highway data (right panel). My analysis shows that: (1) by using uniform 1.5 mile segment lengths, the percentage of highway miles driven by the Diesel Test Vehicle below 0.09 g/mi increases and, (2) filtering the data (even as arbitrarily segmented by Mr. Smithers) to exclude driving outside of HWFET testing conditions in terms of temperature and road grade brings the percentage of miles below the 0.09 g/mi HWFET emissions standard to approximately 70% of the highway miles driven by the Diesel Test Vehicle.

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289 Road grade in this analysis follows Mr. Smithers' flawed definition of road grade, discussed in detail in Section 6.4.1.

290 [redacted]

291 Existing PEMS protocols for on-road evaluations include adjustment and conformity factors that effectively increase the emissions limits above 2x the standard when comparing on-road PEMS data to dynamometer limits. See Appendix E.

292 Smithers Report, ¶ 132.

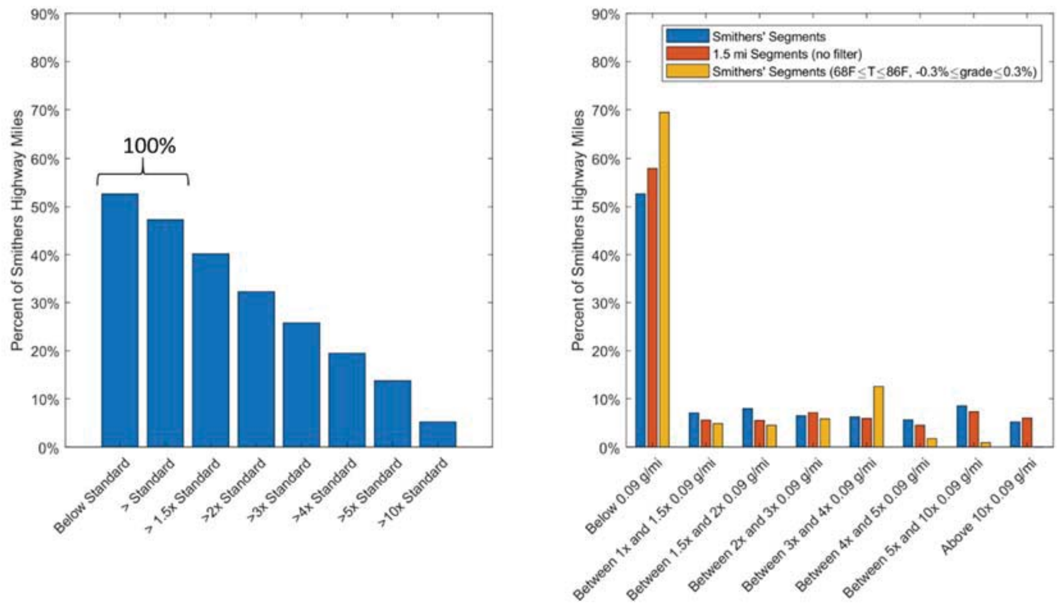

Figure 6-22 (Left) Plot reproduced from the report of Mr. Smithers shows the fraction of highway drive miles traveled by the Diesel Test Vehicle at various multiples of the HWFET standard (0.09 g/mi). (Right) My analysis of the same highway-drive segments but presented in a histogram plot. In this representation, the sum of all percentage values equals 100%, as opposed to Mr. Smithers' plot in which the sum is well above 100%.

Based on this flawed data presentation style, Mr. Smithers makes several factually inaccurate statements including the following:

- "When tested in normal driving conditions, emissions are often as high as 36 times the relevant standard…"[293]
    - This claim is plainly wrong as Mr. Smithers' data shows that only in one segment the Cruze Test Diesel exceeded the FTP standard 36 times and that occurred at very high ambient temperature of 108 °F.
    - Moreover, data presented in Figure 6-21 and Figure 6-22 unequivocally shows that even using Mr. Smithers' flawed representation style only 5% of the miles he drove (which were biased for extreme conditions anyway) resulted in NO_x emissions above 10x the relevant standard (which anyway is not relevant since it is for dynamometer testing and not for PEMS testing). Therefore Mr. Smithers' claim that "emissions are often as high as 36 times the relevant standard" is completely unfounded.

293 Smithers Report, ¶ 21.

- "In many real-world operating conditions described in this report, emissions are more akin to vehicle emissions from cars produced 50 years ago than to cars produced in the last 5 years."[294]
    - The 1973 Chevrolet Vega, a gasoline vehicle referenced by Mr. Smithers, was certified to 2100 mg/mi of NO_x which is 30 times the FTP certification limit of the Cruze diesel. Again data presented in Figure 6-21 and Figure 6-22 unequivocally shows that even using Mr. Smithers' flawed representation style only a tiny fraction of the miles he drove (which were biased for extreme conditions anyway) showed NO_x emissions above 10x the relevant standard (which anyway is not relevant since it is for dynamometer testing and not for PEMS testing).
- "It is clear that the vehicle was calibrated so that low NOx emissions occur only in the test cycles."[295]
    - Even with all the factors Mr. Smithers overlooked that can impact emissions and testing under a wide variety of driving conditions, including extreme temperature conditions, and his flawed segmentation approach, approximately 16% of his stop-and-go driving and 53% (a *majority*) of his highway driving were below the FTP and HWFET NO_x emissions limits (Figure 6-21 and Figure 6-22).

6.4.3 Mr. Smithers' Data Analysis Ignores Drift Corrections

Mr. Smithers produced 67 "raw" Excel files related to his PEMS testing of the Diesel Test Vehicle, each one corresponding to an individual route driven during Mr. Smithers' testing. All of the raw files included instantaneous emissions data collected by the PEMS unit and many of them also included data from the engine control unit (ECU) which was collected using an OBD data logger. Of these 67 raw files, 60 were processed by Mr. Smithers to generate the results and plots contained in his report.

The raw data files are generally structured in columns of data sampled at one second intervals. At the end of each file there is a section with data summaries generated by the PEMS software. The PEMS unit needs to be calibrated the beginning and at the end of each

294 Smithers Report, ¶ 309.

295 Smithers Report, ¶ 21. For example, this PEMS route measured an ambient temperature of 108°F, which is much higher than the FTP temperature range and higher even than the SC03 temperature range. Smithers uses the 0.07 g/mi standard to calculate that NO_x emissions that are 36 times the federal standard. Using the SC03 standard of 0.2 g/mi, however, would make the NO_x levels 12.6 times the federal standard. (This, of course, ignores the fact that (1) this PEMS route had other unique characteristics, including a grade of 0.3%, and (2) there is no applicable standard at an ambient temperature of 108°F.) This is also above the temperate at which GM disclosed EGR would be shutoff to prevent engine overheating thus higher emission are not unexpected.

drive, which enables it to calculate the "Drift Corrected" overall emissions for the drive, which are reported in the summary section.

In his data analysis, Mr. Smithers used the column titled "corrected instantaneous mass NO_x," also labeled kNO_x, to calculate NO_x emissions. Because Mr. Smithers segmented the data from his test drives into smaller segments, he could not use the "Drift Corrected" data reported by the PEMS unit (which was only available as a summary for the entire drive) and had to rely on the instantaneous corrected NO_x data, which is not corrected for drift.

Moreover, for the on-road testing Mr. Smithers conducted in 2016 of the Diesel Test Vehicle, the raw Excel files produced by Mr. Smithers do not include the "Drift Corrected" summaries at all. It is unclear whether Mr. Smithers did not save this information or if he deleted it from the Excel files he produced. Notably however, the difference between drift-corrected and the non-drift corrected summary NO_x emissions can be substantial. Figure 6-23 plots the percentage difference between the drift corrected and the non-drift corrected NO_x emissions averaged over an entire test cycle for the remaining 49 data files that included the relevant information (and that were processed and used by Mr. Smithers). When calculating the difference between the drift-corrected and the non-drift corrected summary NO_x emissions, the average difference was 2%, with one drive showing almost a 19% difference.

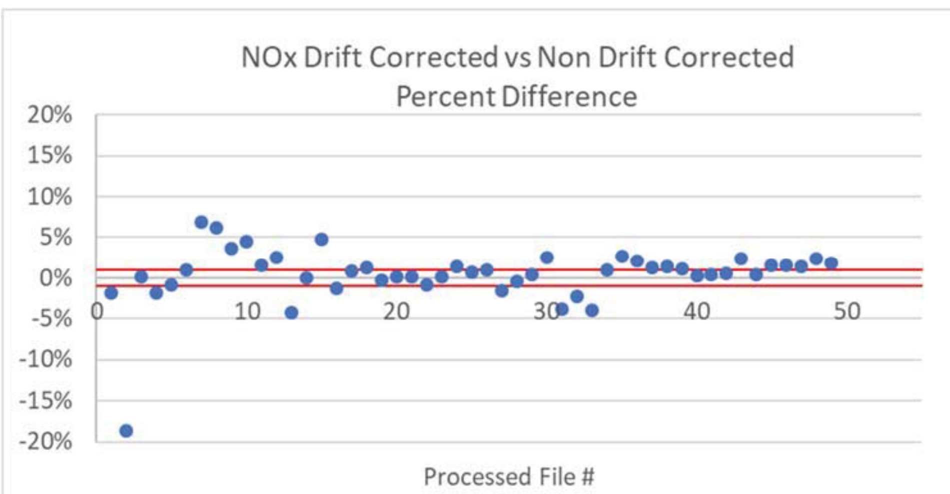

Figure 6-23 Difference between drift corrected and non-drift corrected NO_x emissions measurements for the Diesel Test Vehicle data. The two horizontal red lines represent +-1% bounds.

In his report, Mr. Smithers stated that "The analyzers are also calibrated before and after each test to ensure that they are both accurate and free of excessive drift. Drift has been shown to be far less than 1%, even after several hours of testing. PEMS also employs high accuracy temperature and relative humidity measurements to adjust NO_x."[296] However, the data that he collected and analyzed far exceeded the drift bounds that he claimed, which calls into question the reliability of Mr. Smithers' use of non-drift corrected NO_x emissions and his

296 Smithers Report, ¶ 87.

understanding of his own data, and is further representative of Mr. Smithers' flawed testing methodology.

7 PLAINTIFFS' EXPERTS' CONCLUSIONS REGARDING DEFEAT DEVICES ARE INCORRECT

Both the Smithers and Levchenko Reports suggest that GM failed to disclose to the EPA key features of the emissions controls on the Vehicles.[297] In order to evaluate these claims, I have also reviewed the data and documents cited in their reports, as well as other relevant deposition testimony and documents produced in this matter, including test data submitted to the EPA by GM as part of the Cruze certification process. I disagree with many aspects of Mr. Smithers' and Dr. Levchenko's analyses, and the conclusions drawn from these flawed analyses. In my opinion, there are valid engineering justifications for the AECDs that are alleged by Mr. Smithers and Dr. Levchenko to be defeat devices, and the operation of those AECDs was disclosed. The functional behavior of the emissions control systems (as described by Dr. Levchenko) and the testing data provided by Mr. Smithers are consistent with GM's regulatory disclosures, and I found no evidence of defeat devices.

7.1 GM's AECD Disclosures for the Cruze Diesel

U.S. regulations define an AECD as "any element of design which senses temperature, vehicle speed, engine RPM, transmission gear, manifold vacuum, or any other parameter for the purpose of activating, modulating, delaying, or deactivating, the operation of any part of the emission control system"[298] Mr. Smithers and Dr. Levchenko characterize two aspects of the Subject Vehicles as "defeat devices" which contain "cycle-beating" mechanisms [redacted] They allege that under certain conditions, these emissions control systems function in a way that results in higher NO_x emissions without an appropriate engineering justification or proper disclosure to the EPA.[299]

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297 [redacted]

298 Code of Federal Regulations, Part 86, Section 082-2, available at https://www.govinfo.gov/content/pkg/CFR-2011-title40-vol18/pdf/CFR-2011-title40-vol18-sec86-082-2.pdf.

299 [redacted]

Each of the conditions described in the Smithers and Levchenko Reports was, in fact, disclosed in detail by GM to the EPA in the AECD documents they submitted in connection with both the MY-2014[300] and MY-2015[301] Subject Vehicles' certification processes. The documents for the two model years are materially similar. For convenience and consistency, the remainder of this report cites the MY-2014 AECD disclosure when discussing these documents. The submitted disclosures are comprehensive: each document is 90 pages long and contains a detailed description and the rationale for numerous features of the Cruze Diesel emission controls, including those referenced by Mr. Smithers and Dr. Levchenko. [redacted]

7.1.1 [redacted]

[redacted]

Effective operation of the SCR system is controlled by the EDC system. The EDC monitors SCR conversion efficiency and other parameters to ensure proper functioning of the SCR system and to deliver the appropriate dosage of ammonia to the catalyst. In mobile applications such as the Subject Vehicles, ammonia is supplied in the form of urea (a component of Diesel Exhaust Fluid, or "DEF") which is injected upstream of the SCR catalyst.[303] If too little DEF is dosed, the SCR will not have enough ammonia present to reduce NO_x efficiently. If too much DEF is injected, the excess can initially be stored as adsorbed ammonia on the SCR surface, but once the adsorption capacity of the catalyst is

[redacted]

300 [redacted]

301 [redacted]

302 [redacted]

303 Johnson, T. V. (2014). Review of Selective Catalytic Reduction (SCR) and Related Technologies for Mobile Applications. In *Urea-SCR Technology for deNO$_x$ After Treatment of Diesel Exhausts* (pp. 3-31). Springer, New York, NY.

reached, additional injected ammonia could pass through the system and result in ammonia emissions from the tailpipe.[304] This phenomenon is known as "ammonia slip" and avoiding its occurrence is a fundamental challenge of exhaust after-treatment system control.[305] The EDC of the Subject Vehicles models the ammonia loading on the catalyst and adapts DEF dosing levels to achieve a target conversion efficiency of NO_x by the SCR unit, and to maintain the appropriate ammonia loading on the catalyst.[306]

[redacted]

304 The capacity of the SCR catalyst is partially a function of the catalyst's temperature (as well as its age and other factors), so it can be constantly in flux. The temperature is impacted by the temperature of the exhaust as well as the amount of airflow around the catalyst brick. So, a sudden cooling or heating of the catalyst could cause it to lose the ability to hold some store ammonia, meaning that if it is constantly filled to its maximum capacity, it could suddenly slip ammonia if there is a heating or cooling spike (such as a sudden hard acceleration, or suddenly going downhill in a coast). The EDC therefore must constantly monitor conditions and adapt to fluctuations in the catalyst's ability to hold ammonia, all while the catalyst's existing load is also being consumed by NO_x flowing through it. Hsieh, Ming-Feng, "Control of Diesel Engine Urea Selective Catalytic Reduction Systems, " pp.10-12

305 Dr. Levchenko acknowledges that "the amount of DEF used must also be carefully controlled. Excess DEF dosing results in the emission of ammonia, another pollutant, as well as requiring more frequent refills." Levchenko Report, ¶ 13. *See also*, Levchenko Deposition, 216:23-217:9.

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7.2.4.1 Mr. Smithers' Ambient Temperature Measurements Are Not Measuring the Relevant Temperature

It is important to consider that the ambient air around a vehicle is not a single, uniform temperature and can be influenced by various environmental factors including the presence of other vehicles, wind, and solar radiation. One particularly relevant consideration is solar radiation, which does not appreciably heat the air as it passes through the Earth's atmosphere. Instead, most of the energy from the sun passes through the air and is absorbed by the ground, which in turn heats the air. This naturally means that on sunny, dry days the air closer to the ground will be warmer than the air further from the surface, with the local air

381 [redacted]

382 [redacted]

383 [redacted]

temperature of the air depending on proximity to the ground and the surface temperature of the ground. This effect is depicted in Figure 7-12 below, though this phenomenon is certainly not uniform or consistent and can vary depending on cloud cover, time of day, and angle of solar incidence.

Because the ambient air temperature is not uniform around a vehicle, it is important to consider what precisely the OAT model is intended to model. Mr. Smithers installed the PEMS weather probe on the roof of his vehicle, approximately 5 ft. above ground level.[384] In contrast, the radiator and engine intakes air at about 2 ft. above the ground. At his deposition Mr. Smithers conceded that the temperature could be different at these locations, but added that he did not account for the difference in local ambient because he wanted to capture the "true environmental temperature far from the road."[385] [redacted]

384 *See* Smithers Report, Figure 10-41.

385 Smithers Deposition Vol. II, 307:9-11.

386 [redacted]

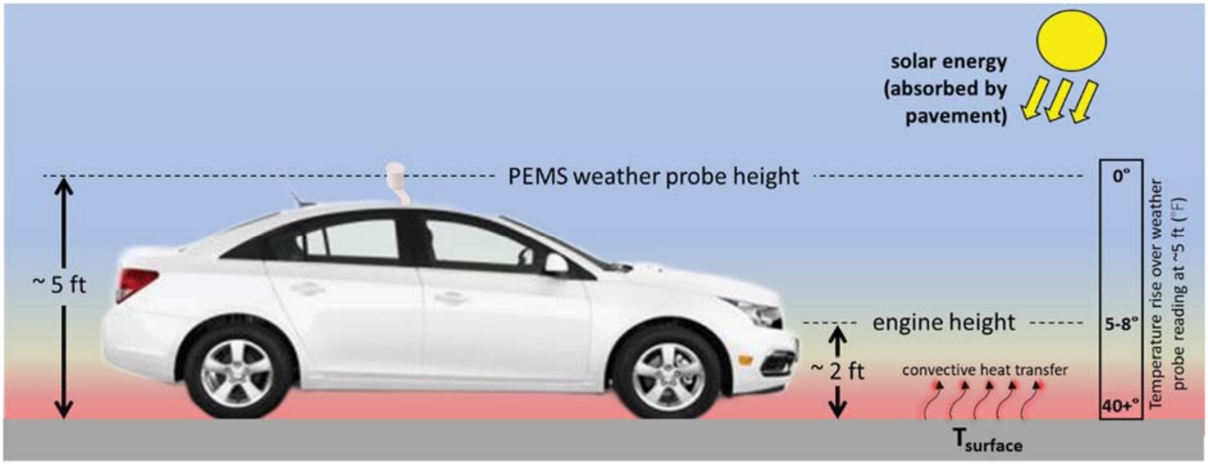

Figure 7-12 Schematic diagram showing the variation in temperature as a function of height above the road surface. The road is generally heated to a higher temperature than the ambient air by absorption of solar radiation, causing a temperature gradient in the vertical direction. The temperature at the engine height, ~2 ft. from the road for the Cruze, is the temperature relevant to the EGR reduction AECD.

To evaluate the local effect of road temperature on ambient temperature, Solaimanian and Kennedy developed a model to predict asphalt temperature as a function of far-field ambient temperature (i.e., greater than 5 ft. above the ground, above the thermal boundary layer) and site latitude (which influences the incidence angle of solar radiation).[387] At a latitude of 34 °N, corresponding to Palm Springs, CA where the data corresponding to the majority of the outliers in Mr. Smithers' Figure 10-42 was collected, the surface temperature can be as high as 44 °F above ambient. In other words, in a far-field ambient of 100 °F (corresponding to the PEMS weather probe reading), the asphalt surface temperature could be as high as 144 °F.

The surface temperature can be used in conjunction with experimental data for near-surface air temperature provided by Duncan[388] to estimate the range of temperatures at engine height. Duncan used an array of integrated-circuit temperature sensors to measure the local air temperature at varying heights up to 5 ft. above the pavement surface from June to August 2011 at locations in and around Clemson, SC. Data from 18 different trials conducted by Duncan were normalized using the measured surface and far-field ambient air temperatures for each trial. These data were then used in Figure 7-13 to estimate the range of possible temperatures at engine height (i.e. at roughly 2 ft. off the ground) for the scenario where the road surface temperature is 144°F and the air 5 ft. above ground (labeled T_{PEMS}) is 100 °F.

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387 Solaimanian, Mansour, and Thomas W. Kennedy. "Predicting Maximum Pavement Surface Temperature Using Maximum Air Temperature and Hourly Solar Radiation." *Transportation* research record 1417 (*Research Record*, 1993): pp. 1-11.

388 Duncan, David, "INFLUENCE OF PAVEMENT TYPE ON NEAR SURFACE AIR TEMPERATURE" (2011). "Influence of Pavement Type on Near Surface Air Temperature," available at https://tigerprints.clemson.edu/all_theses/1277.

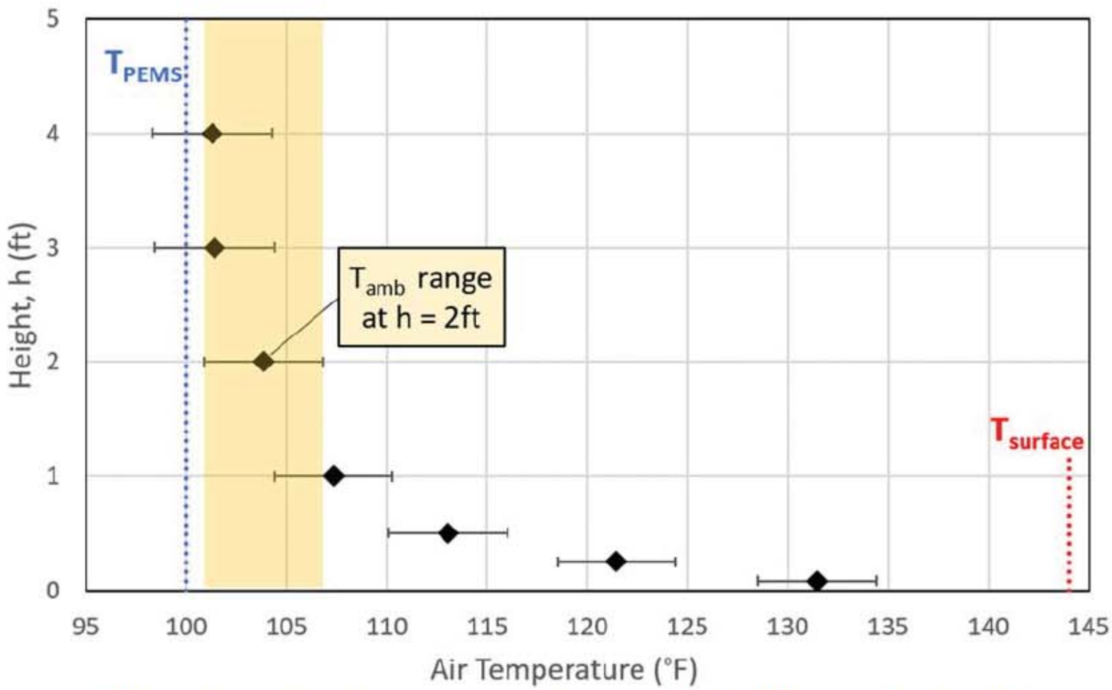

Figure 7-13 Range of possible air temperatures as a function of height off the ground with a bulk air temperature of 100°F and a surface temperature of 144 °F. The error bars are based off a confidence interval of 99% using the variance in the 18 trials in Duncan's study in Clemson, SC.

Overlaying this temperature offset on Mr. Smithers' Figure 10-42 in Figure 7-14 shows that much of the offset for the vehicle temperature model (OAT Temp) from the 'parity plot' with the PEMS weather probe sensor (PEMS Temp) could be explained primarily by this difference in ambient air temperature at 2 ft. off the ground (engine intake grill height) as opposed to 5 ft. off the ground (PEMS weather probe height) [redacted] ather, it reflects that there can be actual, expected differences in ambient temperature at PEMS weather probe height and the engine intake air height under certain weather conditions.

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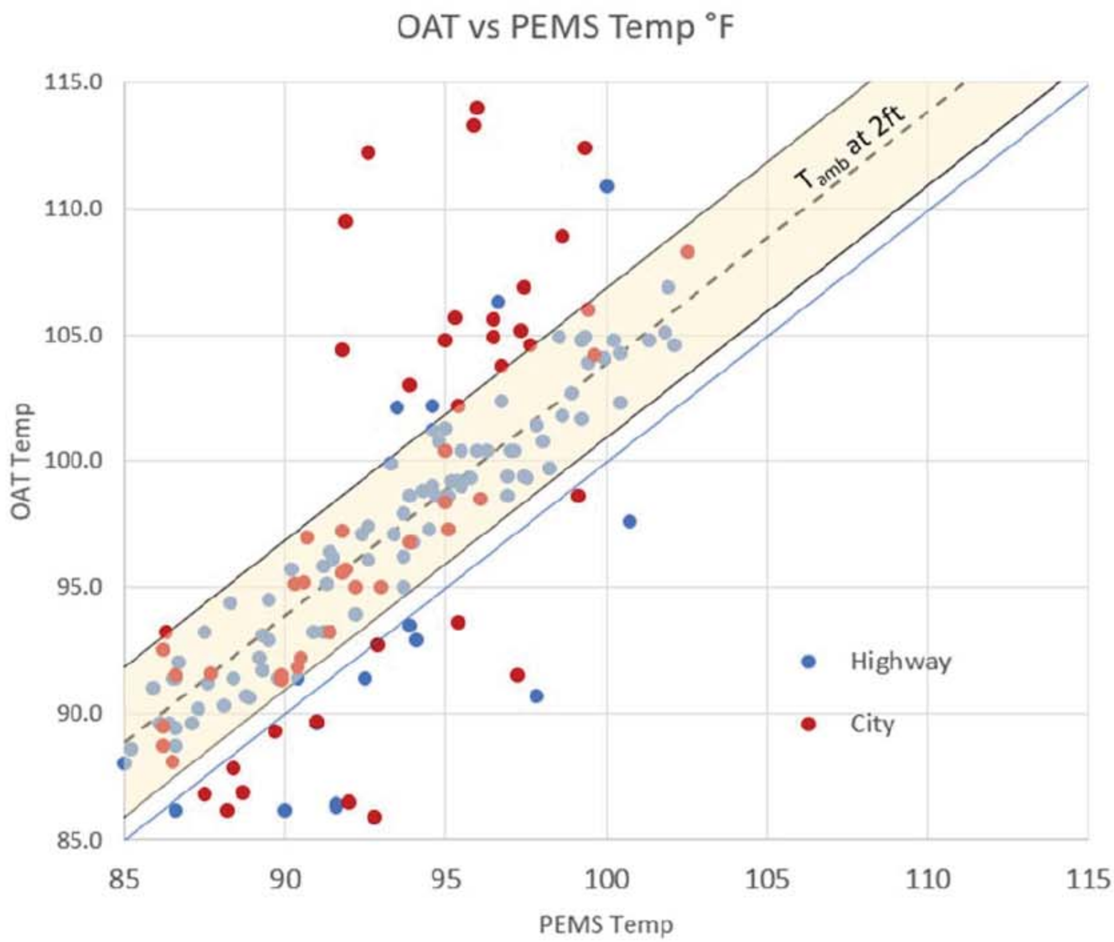

Figure 7-14 Range of expected ambient temperature at 2ft off the road surface (engine intake grill height) plotted versus PEMS temperature.

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7.2.4.4 Mr. Smithers Exaggerates Discrepancies between the OAT Modeled Temperature and the PEMS Ambient Temperature Measurements

Mr. Smithers presents data comparing the OAT model temperature to ambient temperature measurements recorded during his PEMS testing. He asserts that the measurements he recorded, using a temperature probe attached to his test vehicles, reflect the "actual" ambient temperature. In multiple figures in his report, with different ranges of temperatures used for the x- and y- axis on each, he compares the OAT modeled temperature from the test vehicle to his own measurements.[412] The first issue to note is that the use of tighter axis scale ranges for Mr. Smithers' Figures 10-42 and 10-44 for high and low ambient temperatures, respectively, magnifies the appearance of any discrepancy in the OAT and PEMS temperature measurement, particularly in comparison to the parity plot for moderate temperatures ranging from 30°F - 80°F in his Figure 10-43. I have consolidated all of Mr. Smithers' data onto a single plot in the right side of Figure 7-24, spanning the entire temperature range of -10°F - 115°F to show all data points on a single axis without any magnification of the discrepancies at higher and lower temperatures.

[412] *See* Smithers Report, ¶¶220-226.

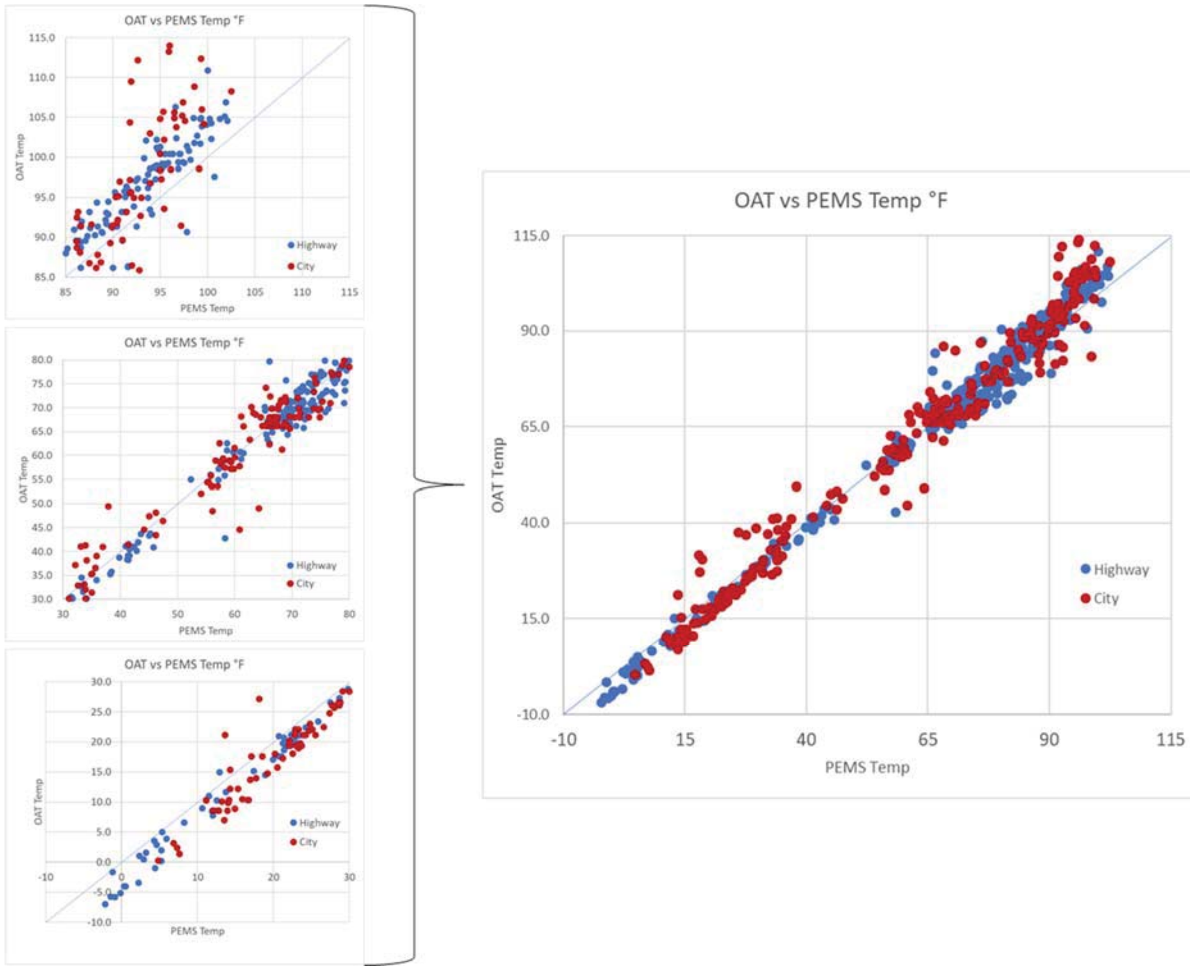

Figure 7-24 Mr. Smithers' original Figures 10-42 (top left), 10-43 (middle left) and 10-44 (bottom left) combined into a single plot (right).

When presenting the same analysis for the Gasoline Test Vehicle, Mr. Smithers does not present the data in such a manner that exaggerates the discrepancies at higher and lower temperatures. For the Gasoline Test Vehicle, Mr. Smithers included the entire data range on a single plot in Figure 10-45 of his report. This presentation of the data makes the discrepancies between the data and the parity line appear less significant than in comparison to the Diesel Test Vehicle, but that appearance is an illusion resulting from Mr. Smithers' distinct presentations of the data for the two vehicles. To illustrate this point, Figure 7-25 below compares the consolidated version of Figures 10-42 through 10-44 for the Diesel Test Vehicle to Figure 10-45 for the Gasoline Test Vehicle presented on identical axes. Here, the discrepancies between the two vehicles are no longer apparent.

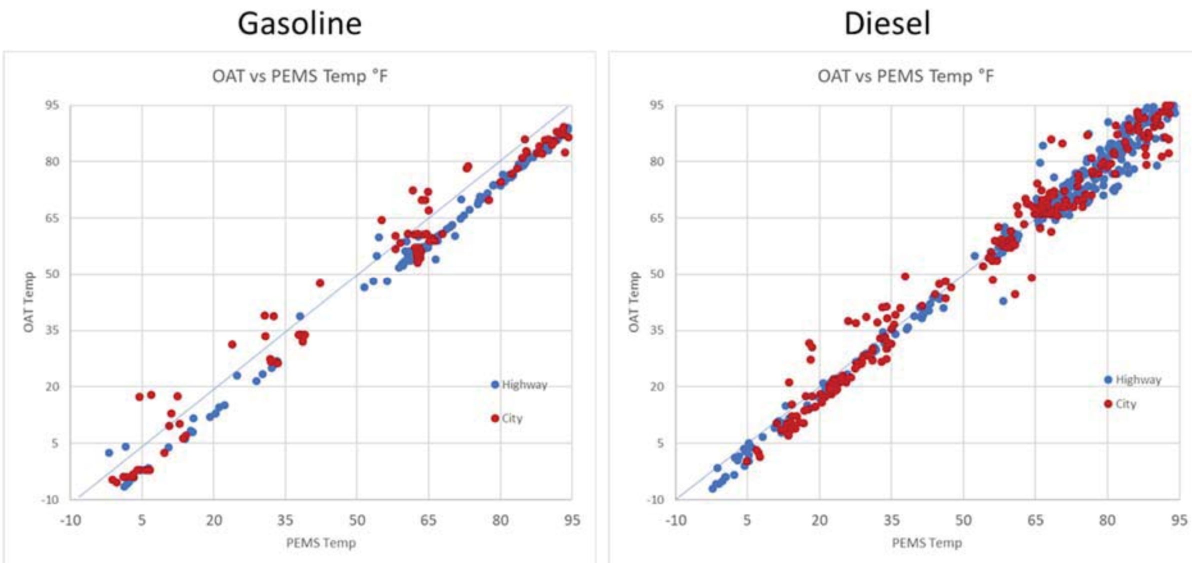

Figure 7-25 Gasoline vehicle data from Mr. Smithers' Figure 10-45 (left) compared to Diesel Test Vehicle data contained in Figures 10-42, 10-43 and 10-44 plotted on a single axis with identical limits to Figure 10-45 (right).

8 PLAINTIFFS' EXPERTS MISCHARACTERIZE EPA GUIDANCE

In his report, Mr. Smithers references documents published by the EPA with guidance related to on-road emissions.[413] However, Mr. Smithers fails to consider these documents in their appropriate context.

Some of the references cited by Mr. Smithers were written decades ago,[414] at a time when emissions standards were much less stringent. For example, Mr. Smithers cites a 1972 EPA advisory circular that was published almost a decade before Tier 0 emissions standards for light-duty vehicles were established and allowable NO_x emissions were 1 g/mi, over an order of magnitude higher than the 0.07 g/mi standards for NO_x emissions on the FTP-75 in Tier 2.[415]

Furthermore, in 1972 diesel exhaust after-treatment technology demonstrated nowhere near the complexity of that used in modern day diesel vehicles. Modern diesel after-treatment technologies rely on sophisticated catalysts such as the SCR, which requires precise monitoring and control to function properly, and operate at different efficiency under different conditions. [416,417] For example, the SCR operates most efficiently within a specific temperature range.[418] Furthermore, the SCR requires appropriate dosing of DEF to reduce NO_x emissions while limiting ammonia slip, and such dosing would not be possible without sensors that monitor NO_x and ammonia in the exhaust stream, or without a control system in the ECU that adapts DEF dosing according to the readings from these sensors. None of the complexities inherent in modern SCR systems would have been contemplated by regulators publishing guidance documents for vehicle manufacturers in 1972, for the simple reason that after-treatment systems were not used.

Indeed, in subsequent circulars the EPA explicitly acknowledges these technological changes and their impact on regulatory guidance. EPA Advisory Circular 24-2 was issued on December 6, 1978 and "supplements" the 1972 Advisory Circular that Mr. Smithers cites in his report.[419] In that Circular, the EPA identified a development that had occurred which

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413 Smithers Report, Section 10.2.5.

414 Mr. Smithers relies on EPA documents written as early as 1972. *See* Smithers Report, ¶ 251.

415 "Light-Duty Vehicles and Light-Duty Trucks: Tier 0, Tier 1, National Low Emission Vehicle (NLEV),and Clean Fuel Vehicle (CFV) Exhaust Emission Standards" *Environmental Protection Agency*, EPA-420-B-16-010, March 2016. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100O9ZP.pdf.

416 Automotive Handbook, 7th Edition, 2007. ISBN 978-0-7680-1953-7

417 Heywood, John B. *Internal Combustion Engine Fundamentals* Vol. 930, New York: McGraw-Hill, Chapter 11, 1988.

418 Hsieh, Ming-Feng, "Control of Diesel Engine Urea Selective Catalytic Reduction Systems, " pp.8-13

419 EPA Advisory Circular No. 24-2 (published December 6, 1978) at p. 1.

"indicated the need to provide additional guidance to the manufacturers regarding defeat devices" since Circular 24 "was published in 1972 (almost six years ago):

> "The [] development has been the rapid advance in the introduction of more sophisticated emission control systems, especially those that offer new flexibility in control capability. The most obvious example of this new technology has been the rapid introduction of electronic control and modulation devices."[420]

EPA went on to say that when Circular 24 was published, "most, if not all, AECD's [sic] were much less sophisticated than current and future systems and were easier to evaluate on a subjective basis." Now, however, the "greater flexibility of the new technology" (which "could be used to improve emission control capability") required more specific and objective regulatory guidance.[421]

Mr. Smithers does not account for technological differences or any related context in his discussion of the EPA's 1972 guidance letter.

[redacted]

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420 EPA A/C 24-2 at p. 1.

421 EPA A/C 24-2 at 2; *see also* EPA Advisory Circular No. 24-3 (published January 19, 2001) ("More sophisticated and complex emission controls are being used and the trend toward such controls continues. For the engines designed to meet the 2004 model year standards, EPA anticipates improvements in fuel metering, the use of advanced turbocharger designs and the use of cooled EGR systems, for example, to be common. These systems will be closely controlled using advanced electronics including on board computers, analogous to the trends in light duty emission controls in earlier years. Thus, as was the case for light duty vehicles and trucks, ***the concerns for how best to implement the defeat device prohibitions needs to reflect these technology trends***.") (emphasis added).

422 [redacted]

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[redacted]

The EPA's guidance related to emissions and defeat devices has evolved over time as emissions after-treatment technologies have advanced. Further, the EPA's recognition of emissions-related challenges under certain driving conditions was demonstrated by the introduction of additional dynamometer drive schedules to vehicle emissions standards over time. The NO_x emissions standards for test cycles such as the US06 and SC03 are higher than those for the FTP-75, reflecting the well-known trend that aggressive driving, high ambient temperatures, and high engine loads lead to higher NO_x emissions in real-world driving conditions compared to the conditions of the FTP-75 test.[424] Mr. Smithers fails to recognize these challenges and, instead, relies on outdated EPA guidance from an era when engine and exhaust after-treatment technology did not possess the complexity, nor the effectiveness, of modern day systems. Additionally, as discussed Section 6.2 and Appendix E, Mr. Smithers ignores EPA's guidance and regulations related to the use of "conformity factors" to relate certification test limits to on-road PEMS measurements.

424 "Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements; Final Rule," Federal Register, Vol. 65, No. 28, February 2000, p. 6730.

9 APPENDIX A: CURRICULUM VITAE OF RYAN HARRINGTON

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Professional Profile

Mr. Harrington brings a unique perspective to his clients having worked in the automotive industry and the federal government. His accomplishments include innovative approaches in automotive engineering, technology evaluation, and the analysis and development of federal regulations, policies, and standards, including fuel economy and emissions rulemakings and motor vehicle safety standards. Mr. Harrington specializes in the analysis of complex technical and policy issues related to the development, testing, and deployment of emerging technologies, including automated vehicles, advanced driver assistance systems (ADAS), vehicle-to-vehicle (V2V) communications, and fuel economy improving technologies, while fostering collaboration between industry executives, senior government officials, and engineers. He has evaluated and developed test procedures for ADAS systems; analyzed failure data and conducted root cause analyses for diesel engines and automotive components; developed prototype electric power steering (EPS) systems; performed noise, vibration, and harshness (NVH) investigations and customer acceptance evaluations; led fuel economy studies; and conducted fuel efficient driver training.

Prior to joining Exponent, Mr. Harrington was the Chief of the Technology Innovation and Policy Division at the U. S. Department of Transportation (DOT) Volpe National Transportation Systems Center. He led a cross-functional team of scientists, engineers, and analysts focused on emerging transportation technologies including automated vehicles, connected vehicles, connected/smart cities, and big data. Mr. Harrington and his team assessed alternative policy approaches to overcome technical and policy barriers impacting the deployment of advanced transportation technologies at the local, regional, and national level. He and his team also conducted a scan of Federal Motor Vehicle Safety Standards (FMVSS) to identify potential conflicts with the certification of automated vehicles; reviewed comments submitted in response to the Federal Automated Vehicles Policy (FAVP); and supported automated vehicle research and safety regulation analyses for passenger cars, commercial motor vehicles (CMV), and transit vehicles. Mr. Harrington was invited to the White House Office of Science and Technology Policy's (OSTP) Executive Leadership Retreat at Camp David to identify key priorities and challenges related to the deployment of automated vehicles.

In his previous work at the Volpe Center, as a Senior Engineer, Mr. Harrington led a team that performed engineering analyses and developed fuel-savings, cost, deployment rates and applicability assumptions for light-duty and heavy-duty vehicle technologies, which were incorporated into the National Highway Traffic Safety Administration's (NHTSA) Corporate Average Fuel Economy (CAFE) standard setting compliance and effects modeling. He presented technology analyses at senior level briefings for the White House Office of Management and Budget (OMB), the DOT, the Environmental Protection Agency (EPA), the California Air Resources Board (CARB), and the National Academy of Sciences (NAS). He represented the DOT and participated in executive level meetings with vehicle manufacturers; engine, transmission, and component suppliers; and industry trade associations. Mr. Harrington was personally congratulated and recognized by the President in the Oval Office for his technical contributions to the development of the model years 2017-2025 CAFE standards. Additionally in his role as a Senior

Engineer, Mr. Harrington developed performance specifications, test track and on-road test procedures, and pass/fail criteria for ADAS systems and served as the U.S. DOT/NHTSA's test evaluator for the Integrated Vehicle-Based Safety Systems (IVBSS) crash avoidance program, which evaluated the independent and integrated performance of forward collision, lane departure, lane change/merge, and curve speed warnings.

As a Technical Support Manager at Cummins Inc., Mr. Harrington led Six Sigma fuel economy improvement projects, analyzed customer requirements, and proposed diesel engine/drivetrain changes to improve the fuel efficiency of long-haul trucks. He analyzed failure data and conducted field investigations to identify the root cause of diesel engine failures and brought resolution to customer product issues. In his role as a Vehicle Test Operations Manager at Environmental Testing Corporation, Mr. Harrington coordinated Federal Test Procedure (FTP) dynamometer emissions testing by interfacing with customer engineers and managing technicians. While working at Delphi Automotive Systems, as a Product Development Engineer, Mr. Harrington led the design and integration of prototype EPS systems into customer developmental vehicles. Using Shainin ® Red X methodologies, he performed NVH identification and consumer acceptance evaluations of EPS systems at customer and Delphi facilities in Poland, Italy, and Germany.

Mr. Harrington's passion for motor vehicles and automotive engineering extends beyond his professional career. He is a volunteer design judge for the Formula Hybrid Competition, which is part of the Society of Automotive Engineers (SAE) Collegiate Design Series. Mr. Harrington continues to develop his vehicle dynamics knowledge and driving skills by competing in Sports Car Club of America (SCCA) and Porsche Club of America (PCA) autocross racing.

Academic Credentials & Professional Honors

M.E., Automotive Engineering, University of Michigan, Ann Arbor, 2004

B.S., Mechanical Engineering, University of Nebraska, 1999

Recipient of the U.S. DOT Secretary's Gold Medal Award (DOT's highest award), 2008

Prior Experience

Division Chief, U.S. DOT Volpe National Transportation Systems Center, 2012-2017

Senior Engineer, U.S. DOT Volpe National Transportation Systems Center, 2007-2012

Technical Support Manager, Cummins Inc., 2004-2007

Vehicle Test Operations Manager, Environmental Testing Corporation, 2004

Design Responsible Engineer, Delphi Automotive Systems, 2000-2004

Engineering Intern, Goodyear Tire & Rubber Company, 1998-1999

Professional Affiliations

Society of Automotive Engineers (SAE)

Publications

Harrington R, Senatore C, Scanlon J, Yee R. The Role of Infrastructure in an Automated Vehicle Future. National Academy of Engineering - The BRIDGE Volume 48, Number 2, Summer 2018.

Lange R, Kelly S, Senatore C, Wilson J, Yee R, Harrington R. Data Requirements for Post-Crash Analyses of Collisions Involving Collison Avoidance Technology Equipped, Automated, and Connected Vehicles. ESV 2017 Paper Number 17-0338, June 2017.

Kim A, Perlman D, Bogard D, Harrington R. Review of Federal Motor Vehicle Safety Standards (FMVSS) for Automated Vehicles: Identifying potential barriers and challenges for the certification of automated vehicles using existing FMVSS. DOT VNTSC OSTR 16 03, March 2016.

Bettisworth C, Burt M, Chachich A, Harrington R, Hassol J, Kim A, Lamoureux K, LaFrance-Linden D, Maloney C, Perlman D, Ritter G, Sloan S, Wallischeck E. Status of the Dedicated Short-Range Communications Technology and Applications: Report to Congress. FHWA JPO 15 218, July 2015.

Shaulov M, Green K, Harrington R, Mergel J, Pickrell D, Keefe R, Van Schalkwyk J. 2017 - 2025 Corporate Average Fuel Economy Compliance and Effects Modeling System Documentation. DOT HS 811 670, August 2012.

Van Schalkwyk J, Green K, Pickrell D, Harrington R, Shaulov M. 2012 - 2016 Corporate Average Fuel Economy Compliance and Effects Modeling System Documentation. DOT HS 811 301, March 2010.

Harrington R, Lam A, Nodine E, Ference J, Najm W. Integrated Vehicle-Based Safety Systems Light-Vehicle On-Road Test Report. DOT HS 811 020, August 2008.

Harrington R, Lam A, Nodine E, Ference J, Najm W. Integrated Vehicle-Based Safety Systems Heavy-Truck On-Road Test Report. DOT HS 811 021, August 2008.

Selected Invited Presentations

Harrington R. Advanced Driver Assistance Systems. Presenter and panelist, Product Liability Advisory Council (PLAC) Fall Conference, Dana Point, CA, November 1-2. 2018

Harrington R. Autonomous Vehicles: The Good, The Bad, & The Ugly. Presenter and panelist, American Bar Association - Webinar, October, 2, 2018.

Harrington R. The Changing Nature of Driving: Implications of Advanced Driver Assistance Systems (ADAS) and Highly Automated Vehicles (HAV). Presenter and panelist, The Bar Association of San Francisco - Webcast, San Francisco, CA, July 11, 2018.

Harrington R. An AV Crash Occurs: What Happens Next?. Panelist, Automated Vehicles Symposium 2018, San Francisco, CA, July 9-12, 2018.

Harrington R. Paving the Road to ADAS & Automated Driving with Embedded Systems. Panelist, Embedded Systems Conference 2018, Boston, MA, April 18-19, 2018.

Harrington R. The Passenger Cabin of the Future: Alternative Cabin Layouts for Autonomous Vehicles. Presenter and panelist, American Bar Association - 2018 Emerging Issues in Motor Vehicle Liability Litigation Conference, Phoenix, AZ, April 5-6, 2018.

Harrington R. An Automated Vehicle Crashes: What Happens Next?. Panelist, Automated Vehicles Symposium 2017, San Francisco, CA, July 11-13, 2017.

Harrington R. Societal Perspectives on Safety Assurance. Presenter and panelist, Automated Vehicles Symposium 2017, San Francisco, CA, July 11-13, 2017.

Harrington R. The Future of Vehicle Fuel Efficiency & Emissions Policies. Panelist, Motor & Equipment

Manufacturers Association (MEMA) - 2017 Legislative Summit, Washington, DC, May 16-18, 2017.

Harrington R. Automated Vehicles: The Evolving Landscape and Product Litigation Considerations. Presenter and panelist, American Bar Association - 2017 Emerging Issues in Motor Vehicle Liability Litigation Conference, Phoenix, AZ, April 6-7, 2017.

Harrington R. Exploring Autonomous Technology within Greater Boston. Panelist, Association for Unmanned Vehicle System International (AUVSI) New England - Autonomous Vehicles Summit 2017, Cambridge, MA, March 2, 2017.

Harrington R. Automated and Connected Vehicles: Overview and USDOT Role. Eighth Annual Autonomous Guidance, Navigation and Control (AGN&C) Symposium, Draper Laboratories, Cambridge, MA, November 3, 2016.

Harrington R. Automated and Connected Vehicles: Overview and USDOT Role. American Council of Engineering Companies (ACEC) 2016 Fall Conference, Colorado Springs, CO, October 21, 2016.

Harrington R. CAFE Compliance and Effects Modeling System - Overview. National Academy of Sciences Committee Meeting - Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles - Phase 2, Washington, DC, June 20-21, 2012.

Harrington R. Passenger Car and Light Truck CAFE Analysis and Technology Inputs. National Academy of Sciences Committee Meeting - Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles, Ann Arbor, MI, June 18-19, 2009.

Harrington R. Light Vehicle and Heavy Truck Test Track Verification Test Results. Integrated Vehicle-Based Safety Systems 2008 Public Annual Meeting, Ypsilanti, MI, April 10-11, 2008.

Additional Education & Training

Society of Automotive Engineers' (SAE) - Powertrain Selection for Fuel Economy and Acceleration Performance and Turbocharging for Fuel Economy and Emissions, 2009

Six Sigma Green Belt Training, 2005

Shainin ® Red X Problem Solving Training, 2003

General Motors Advanced Driver Training, 2001

Peer Reviewer

Serves as a peer reviewer at the Department of Energy's (DOE) Annual Merit Review (AMR)

10 APPENDIX B: TESTIMONY HISTORY OF RYAN HARRINGTON

List of Depositions and Trial Testimony for Ryan J. Harrington

Depositions

1. Shelby Zelonis v. Volkswagen Group of America, Inc. August 10, 2017 in the Circuit Court for the County of Fairfax, State of Virginia, Civil Action No. CL2015-13746.

2. Michael J. Taylor and Vicky M. Taylor v. Circle Motors, Inc. dba South Bay Volkswagen. September 25, 2017, Judicate West Case No. A228160-48.

3. Laura A. Frerking and Robert J. Frerking v. Dirito Brothers Walnut Creek, Inc. dba Dirito Brother Volkswagen. September 25, 2017, ADR Services Case No. 16-7063-MRD.

4. Caleb Lugliani v. Brothers Walnut Creek, Inc. dba Dirito Brother Volkswagen. September 25, 2017, ADR Services Case No. 16-7064-MRD.

5. Taner Pamuk and Sarah D. Hartmann v. M&M Automotive Group, Inc. dba Volkswagen of Oakland. September 25, 2017, JAMS Case No. 1100086552.

6. Ramin Moosa v. Ford Motor Company, et al. January 16, 2018 in the Superior Court of California, County of San Diego, Case No.: 37-2016-00041776-CU-BC-CTL.

7. Vanessa F. Martinez v. Ford Motor Company. January 16, 2018 in the Superior Court of California, County of San Diego, Case No.: 37-2016-00041095-CU-BC-CTL.

8. David Howard Doar v. Volkswagen Group of America, Inc. f/k/a Volkswagen of America, Inc. January 31, 2018 in the Circuit Court for the County of Fairfax, State of Virginia, Case No.: CL-2017-229.

9. Leonila V. Ambriz and Erik Ambriz v. Ford Motor Company. March 16, 2018 in the Superior Court of California, County of Riverside, Case No.: RIC1612390.

10. Daniel Mora v. Ford Motor Company. May 14, 2018 in the Superior Court of California, County of San Diego, Case No.: 37-2016-00041099-CU-BC-CTL.

11. Jesus M. Torres v. Ford Motor Company. May 14, 2018 in the Superior Court of California, County of Los Angeles, Case No.: BC609910.

12. David Afzal and Andy Dechartivong v. BMW of North America, LLC and Bavarian Motors Works. July 10, 2019 in United States District Court for the District of New Jersey, Civil Action No.: 15-8009 (MCA)(LDW).

13. Clendenen v. Volkswagen Group of America Inc., et al. January 7, 2020 in United States District Court for the Northern District of California, Case No. 3:18-cv-07040-CRB.

14. Coon, et al v. Volkswagen Group of America Inc., et al. January 7, 2020 in United States District Court for the Northern District of California, Case No. 3:18-cv-06966-CRB.

15. Ortiz, et al v. Volkswagen Group of America Inc., et al. January 7, 2020 in United States District Court for the Northern District of California, Case No. 3:18-cv-06951-CRB.

16. Riley v. Volkswagen Group of America Inc., et al. January 7, 2020 in United States District Court for the Northern District of California, Case No. 3:17-cv-02897-CRB.

17. Robertson v. Volkswagen Group of America Inc., et al. January 7, 2020 in United States District Court for the Northern District of California, Case No. 3:18-cv-06956-CRB.

18. Salzer v. Volkswagen Group of America Inc., et al. January 7, 2020 in United States District Court for the Northern District of California, Case No. 3:18-cv-07050-CRB.

19. Sanwick, et al v. Volkswagen Group of America Inc., et al. January 7, 2020 in United States District Court for the Northern District of California, Case No. 3:17-cv-03032-CRB.

Arbitrations

1. Michael J. Taylor and Vicky M. Taylor v. Circle Motors, Inc. dba South Bay Volkswagen. October 4, 2017, Judicate West Case No. A228160-48.

2. Caleb Lugliani v. Brothers Walnut Creek, Inc. dba Dirito Brother Volkswagen. October 16, 2017, ADR Services Case No. 16-7064-MRD.

3. Laura A. Frerking and Robert J. Frerking v. Dirito Brothers Walnut Creek, Inc. dba Dirito Brother Volkswagen. October 16, 2017, ADR Services Case No. 16-7063-MRD.

4. Michelle L. Pennings v. Drew Ford dba Drew Volkswagen v. Ford Motor Credit Company, LLC. November 21, 2017, AAA Claim No. 01-17-0000-8782.

5. Taner Pamuk and Sarah D. Hartmann v. M&M Automotive Group, Inc. dba Volkswagen of Oakland. December 20, 2017, JAMS Case No. 1100086552.

6. Timothy Hassett v. Q&S Automotive, LLC, dba Audi Oakland. March 7, 2018, NAM Case No. 200830.

7. Evan Lippincott and Emily Lippincott v. PAG Santa Ana AVW, Inc., dba Audi South Coast. April 24, 2018, NAM Case No. 207302.

11 APPENDIX C: RELIANCE MATERIALS

Appendix C

Reliance Materials

Legal Documents

Stipulated Order for Inspection Protocol for Mr. Smithers' Test Vehicles and PEMS Test Equipment, Case No. 1:16-cv-12541-TLL-PTM, State of Michigan, Eastern District Court, filed February 13, 2020.

Answer of General Motors LLC to First Amended Complaint, Jason Counts et al. v. General Motors LLC, Robert Bosch GMBH, and Robert Bosch LLC, Case No. 1:16-cv-12541-TLL-PTM, State of Michigan, Eastern District Court, December 18, 2018.

Plaintiffs' First Amended Complaint and Jury Demand, Jason Counts et al. v. General Motors LLC, Robert Bosch GMBH, and Robert Bosch LLC, Case No. 1:16-cv-12541-TLL-PTM, State of Michigan, Eastern District Court, filed June 11, 2018.

Plaintiffs' Complaint and Jury Demand, Jason Counts et al. v. General Motors LLC, Case No. 1:16-cv-12541-TLL-PTM, State of Michigan, Eastern District Court, July 7, 2016.

Depositions

Deposition transcript and corresponding exhibits of Andrew S. Barren, July 12, 2019.

Deposition transcript and corresponding exhibits of Audley F. Brown, July 18, 2019.

Deposition transcript and corresponding exhibits of Jason Counts, October 1, 2018.

Deposition transcript and corresponding exhibits of Rebecca J. Darr, June 18, 2019.

Deposition transcript and corresponding exhibits of José DeLeon, June 12, 2019.

Deposition transcript and corresponding exhibits of Sarah Funk, July 24, 2019.

Deposition transcript and corresponding exhibits of David Garret, October 25, 2018.

Deposition transcript and corresponding exhibits of Thomas Hayduk, November 16, 2018.

Deposition transcript and corresponding exhibits of Christopher Hemberger, April 15, 2019.

Deposition transcript and corresponding exhibits of Bassam Hirmiz, November 5, 2018.

Deposition transcript and corresponding exhibits of Donald Klein, October 2, 2018.

Deposition transcript and corresponding exhibits of Kirill Levchenko, May 19, 2020.

Deposition transcript and corresponding exhibits of Derek Long, June 4, 2019.

Deposition transcript and corresponding exhibits of John Miskelly, October 31, 2018.

Deposition transcript and corresponding exhibits of Steffen Moessner, July 17, 2019.

Deposition transcript and corresponding exhibits of Bruce T. Patton, July 9, 2019.

Deposition transcript and corresponding exhibits of James Perrin, July 19, 2019.

Deposition transcript and corresponding exhibits of David P. Quigley, July 23, 2019.

Deposition transcript and corresponding exhibits of Kevin Respondek, July 11, 2019.

Deposition transcript and corresponding exhibits of Joshua Rodriguez, December 13, 2018.

Deposition transcript and corresponding exhibits of Andreas Sambel, July 2, 2019.

Deposition transcript and corresponding exhibits of Michael E. Siegrist, July 16, 2019.

Deposition transcript and corresponding exhibits of Jason Silveus, October 24, 2018.
Deposition transcript and corresponding exhibits of Juston Smithers, May 20-21, 2020.
Deposition transcript and corresponding exhibits of Robert J. Sutschek, August 8, 2019.
Deposition transcript and corresponding exhibits of Oscar Zamora, May 12, 2019.

Opposing Expert Reports and Reliance Materials

Smithers Report and Reliance Materials

Expert Report of Juston Smithers, Jason Counts et al. v. General Motors LLC, Robert Bosch GMBH, and Robert Bosch LLC, Case No. 1:16-cv-12541-TLL-PTM, State of Michigan, Eastern District Court, October 28, 2019.

2015 Application for Certification, Gasoline Cruze Test Group FGMXV01.8011.pdf
2019_01_22_LDV 1065 C16 NO Linearity Pass.xlsx
2019_01_22_LDV 1065 C16 NO2 Linearity Pass.xlsx
2019_01_22_LDV 1065 C16 stack CO CO2 Linearity Pass.xlsx
2019_01_22_LDV 1065 D18 NO Linearity Pass.xlsx
2019_01_22_LDV 1065 D18 stack CO CO2 Linearity Pass.xlsx
2019_01_22_LDV 1065 D185 NO2 Linearity Pass.xlsx
2019_02_20_LDV 1065 D18 NO Linearity Pass.xlsx
2019_02_20_LDV 1065 D18 stack CO CO2 Linearity Pass.xlsx
2019_02_20_LDV 1065 D185 NO2 Linearity Pass.xlsx
5-25-16 Checkout Test Cruze Semtech with OBD 2018 Reprocess.xlsx
5-25-16 Drive from Oakland to SoCal with OBD 2018 Reprocess.xlsx
5-28-16 Drive from Ojai to Castaic with OBD 2018 Reprocess.xlsx
9510167_2.0 - Referernce Manual.pdf
9510172_1.0 - Quick Start Guide.pdf
Appendix 12.1 CV-Juston Smithers.pdf
Appendix 12.2 Cruze Diesel Records.pdf
Appendix 12.3 Cruze Gasoline Records.pdf
Appendix 12.6 Semtech PEMS System.pdf
Appendix 12.8 Cold CO Results.xls
Appendix 12.8 FTP-75 Results.xls
Appendix 12.8 HWFET Results.xls
Appendix 12.8 US06 Results.xls
C16130965 Comp Cert 5-12-16.pdf
C16130965 Singed Cert 6-5-18.pdf
C16130966 Gas Comp Cert 5-12-16.pdf
C16130966 NOx Gas Lin Cert 5-12-16.pdf

Cold CO FTP and FTP-75 Modal, Temp, SCR Efficiency, NOx(grams per mile) graphs.xlsx
Cruze Equipment Compliance.xlsx
Cruze Vehicle Modification Summary.xlsx
D18505934_signedcompliance_05_09_18 08_30_35.pdf
D18505939 Signed Cert 5-9-18.pdf
EFM_2d0F_2018_01_26_J15127424.pdf
EFM_2d0F_2018_11_05_J15127424.pdf
EFM_2d0FandT_2018_01_26_J15127424.pdf
EFM_2d5F_2016_05_12_E1613292.pdf
EFM_2d5F_2018_03_22_H17139395.pdf
EFM_2d5F_2018_08_06_E1613292.pdf
EFM_2d5F_2018_10_15_H17139395.pdf
EFM_2d5T_2016_05_11_E1613292.pdf
EFM_2d5T_2018_03_22_H17139395.pdf
EFM_2d5T_2018_08_06_E1613292.pdf
G17139306 Signed Comp Cert 8-24-17.pdf
Gas_MULTICOMP_SampleAssy.pdf
Gas_NO2_SampleAssy.pdf
H17139333 Signed Cert 8-14-18.pdf
HGD_5PPRRP30_2018_09_24.pdf
HGD_TER8UCW4_2018_07_17.pdf
HGD_TER8UCW4_2018_09_11.pdf
LDV 1065 G171 H171 CO CO2 Linearity Pass 11-14-18.xlsx
LDV 1065 G171 H171 NO Linearity Pass 11-14-18.xlsx
LDV 1065 C16 stack CO CO2 Linearity(Max Schenk) Pass Aug 3rd.xlsx
LDV 1065 C16 Stack NO Linearity(Max Schenk) Pass Aug 3rd.xlsx
LDV 1065 C16 stack NO2 Linearity(Max Schenk) Aug 3rd..xlsx
LDV 1065 D18 CO CO2 Linearity Pass 11-14-18.xlsx
LDV 1065 D18 NO Linearity Pass 11-14-18.xlsx
LDV 1065 D18 NO Linearity Pass December 19th.xlsx
LDV 1065 D18 NO Linearity Pass Oct 10th.xlsx
LDV 1065 D18 NO2 Linearity Pass Dec 19th 2018.xlsx
LDV 1065 D18 NO2 Linearity Pass Oct 10th.xlsx
LDV 1065 D18 NO2 Linearity(Max Schenk) Pass 11-14-18.xlsx
LDV 1065 D18 stack CO CO2 Linearity Pass December 19th.xlsx
LDV 1065 D185 CO CO2 Linearity Pass Oct 11th.xlsx
LDV 1065 D185 CO CO2 Linearity Pass Sept 11th.xlsx
LDV 1065 D185 NO Linearity Pass Sept 11th.xlsx
LDV 1065 D185 NO2 Linearity Pass Sept 11th.xlsx
LDV 1065 G171 H171 CO CO2 Linearity Pass Dec 15th 2018.xlsx
LDV 1065 G171 H171 NO Linearity Pass Dec 15th 2018.xlsx

LDV 1065 G171 H171 NO2 Linearity Pass 11-14-18.xlsx
LDV 1065 G171 H171 NO2 Linearity Pass Dec 15th 2018.xlsx
LDV Post processing.pdf
LDV_9510-172_Rev 1.10_Testing Guidelines Vio2.docx
Low Pass Filter Calculator.xlsx
LDV_Testing Guidelines Vio3.docx
NOx Reduction Perfomance Research Cruze 2018 Reanalysis 2.pptx
NOx Reduction Perfomance Research Cruze 2018 Reanalysis.pptx
NOx Reduction Perfomance Research Cruze Gasoline.pptx
OCR_Smithers 2015 Diesel Cruze 1G1P75SZ4F7153752.pdf
PEMS Firmware Versions.xlsxPEMS op procedure ver 4.docx
PEMS Overall Summary Cruze for Final Report.xlsx
PEMS Overall Summary Cruze Gasoline for Final Report.xlsx
PEMS Units Modification.xlsx
PP_2016-05-25 10-06-55 cruze prove out test_M01-M02.csv
PP_2016-05-25 19-56-23 LVK to Ojai_M01-M02.csv
PP_2016-05-31 19-11-30 Cruze to Mammoth_M1-M3 Processed with OBD 2018 Reprocess.xlsx
PP_2016-05-27 20-57-42 Ojai S Clarita_M01-M02.csv
PP_2016-05-31 19-11-30 Cruze to Mammoth_M1-M3.csv
PP_2016-06-01 04-19-20 cold mammoth_M1-M3 Processed with OBD 2018 Reprocess.xlsx
PP_2016-06-01 04-19-20 cold mammoth_M1-M3.csv
PP_2016-06-01 07-16-17 bishop 1_M1-M3 Processed with OBD 2018 Reprocess.xlsx
PP_2016-06-01 09-59-35 mojave 2_M1-M3 Processed with OBD 2018 Reprocess.xlsx
PP_2016-06-01 07-16-17 bishop 1_M1-M3.csv
PP_2016-06-01 09-59-35 mojave 2_M1-M3 w OBD time aligned.xlsx
PP_2016-06-01 09-59-35 mojave 2_M1-M3.csv
PP_2016-06-05 06-54-07 Cruze low T transient lightweight_M1-M3 Processed 2018 Reprocess.xlsx
PP_2016-06-05 06-54-07 Cruze low T transient lightweight_M1-M3 with OBD.xlsx
PP_2016-06-05 17-00-44 Cruze high T lightweight_M1-M3 Processed 2018 Reprocess.xlsx
PP_2016-06-05 17-00-44 Cruze high T lightweight_M1-M3 with OBD.xlsx
PP_2016-06-08 12-23-56 Cruze Ojai to Victorville for 100F drive_M1-M3 Processed 2018 Reprocess.xlsx
PP_2016-06-08 12-23-56 Cruze Ojai to Victorville for 100F drive_M1-M3.csv
PP_2016-06-08 15-45-32 cruze victorville stop and go_M1-M3 Processed 2018 Reprocess.xlsx
PP_2016-06-08 15-45-32 cruze victorville stop and go_M1-M3.csv
PP_2016-06-08 18-21-52 cruze victorville to ojai_M1-M3 Processed 2018 Reprocess.xlsx
PP_2016-06-08 18-21-52 cruze victorville to ojai_M1-M3.csv
PP_2018-08-21 15-55-58 Chevy Cruze 2015 Intl Blvd_M1-M4(w obd) Processed.xlsx
PP_2018-08-21 15-55-58 Chevy Cruze 2015 Intl Blvd_M1-M4(w obd).xlsx
PP_2018-08-22 12-31-50 Chevy Cruze Hwy Out To Tracy_M01-M02(w obd) Processed.xlsx
PP_2018-08-22 12-31-50 Chevy Cruze Hwy Out To Tracy_M01-M02(w obd).xlsx

PP_2018-08-23 11-33-38 Chevy Cruze RF to South 5_M1-M4(w obd) Processed.xlsx

PP_2018-08-23 11-33-38 Chevy Cruze RF to South 5_M1-M4(w obd).xlsx

PP_2018-08-23 15-27-01 Chevy Cruze 2015 South 5 to RF_M1-M4 With_OBD Processed.xlsx

PP_2018-08-23 15-27-01 Chevy Cruze 2015 South 5 to RF_M1-M4 With_OBD.xlsx

PP_2018-08-24 12-45-05 Chevy Cruze to Tracy and Valley Driving_M01-M02(w obd) Processed.xlsx

PP_2018-08-24 12-45-05 Chevy Cruze to Tracy and Valley Driving_M01-M02(w obd).xlsx

PP_2018-08-27 11-50-45 2015 Cruze to Tracy and Valley driving below 80F_M01-M02 With OBD Processed.xlsx

PP_2018-08-27 11-50-45 2015 Cruze to Tracy and Valley driving below 80F_M01-M02 With OBD.xlsx

PP_2018-08-28 11-23-39 2015 Cruze RF to Manteca_M1-M4(w obd) Processed.xlsx

PP_2018-08-28 11-23-39 2015 Cruze RF to Manteca_M1-M4(w obd).xlsx

PP_2018-08-28 13-15-28 2015 Cruze in town Manteca_M1-M4(w obd) Processed.xlsx

PP_2018-08-28 13-15-28 2015 Cruze in town Manteca_M1-M4(w obd).xlsx

PP_2018-08-28 15-50-15 2015 Cruze Manteca to RF_M1-M4(w obd) Processed.xlsx

PP_2018-08-28 15-50-15 2015 Cruze Manteca to RF_M1-M4(w obd).xlsx

PP_2018-08-30 11-28-37 Extreme Driving Hills and Heavy Accel_M01-M02(w obd).xlsx

PP_2018-08-30 15-02-29 Hill Driving 2 Marin Ave Grizzly Peak_M01-M02(w obd).xlsx

PP_2018-09-04 15-14-16 2015 Cruze hot Manteca in twn and back to RF_M1-M4_wti_OBD Processed.xlsx

PP_2018-09-04 11-34-13 2015 Cruze hot RF to Manteca with I5_M1-M4_With_OBD_and_MeasTemps.xlsx

PP_2018-09-04 15-14-16 2015 Cruze hot Manteca in twn and back to RF_M1-M4_wti_OBD.xlsx

PP_2018-09-04 18-47-18 I5 Hot HWY Temps and In town Manteca_M1-M3 Processed.xlsx

PP_2018-09-04 18-47-18 I5 Hot HWY Temps and In town Manteca_M1-M3.xlsx

PP_2018-09-05 18-47-18 I5 Hot HWY Temps and In town Manteca_M1-M3(w obd).xlsx

PP_2018-09-06 11-39-09 2015 Cruze RF to Manteca_M1-M4_With_OBD_and_MeasTemps Processed.xlsx

PP_2018-09-06 11-39-09 2015 Cruze RF to Manteca_M1-M4_With_OBD_and_MeasTemps.xlsx

PP_2018-09-06 14-10-00 2015 Cruze Manteca in twn and back RF_M1-M4_With_OBD Processed.xlsx

PP_2018-09-06 14-10-00 2015 Cruze Manteca in twn and back RF_M1-M4_With_OBD.xlsx

PP_2018-09-07 12-26-09 Drive out to Ryer Island for FTP HWFET and SCO3 hot start tests_.xlsx

PP_2018-09-07 12-26-09 Drive out to Ryer Island for FTP HWFET and SCO3 hot start tests_M01-M02 (w obd).xlsx

PP_2018-09-07 15-27-58 SCO3 final_M01-M02(w obd) Processed.xlsx

PP_2018-09-07 15-27-58 SCO3 final_M01-M02(w obd).xlsx

PP_2018-09-12 13-38-50 2015 Cruze in twn Oakland_M1-M4_with_OBD_and_MeasTemps Processed.xlsx

PP_2018-09-12 13-38-50 2015 Cruze in twn Oakland_M1-M4_with_OBD_and_MeasTemps.xlsx

PP_2018-09-17 12-34-55 Drive to Palm Springs_M01-M02(w obd) Processed Online Dosing Plots.xlsx

PP_2018-09-17 12-34-55 Drive to Palm Springs_M01-M02(w obd) Processed.xlsx

PP_2018-09-17 12-34-55 Drive to Palm Springs_M01-M02(w obd).xlsx

PP_2018-09-18 11-13-06 Palm Springs In Town and Salton Sea HWY HOT Temps 90-104_M01-M02(w obd) Processed.xlsx

PP_2018-09-18 11-13-06 Palm Springs In Town and Salton Sea HWY HOT Temps 90-104_M01-M02(w obd).xlsx

PP_2018-09-18 18-31-15 palm springs highway short run to verify analyzer less than 60 miles_M01-M02(w obd).xlsx

PP_2018-09-18 18-31-15 palm springs highway short run to verify analyzer.xlsx

PP_2018-09-19 12-44-31 Salton Sea Rerun part 1(w obd) Processed.xlsx

PP_2018-09-19 12-44-31 Salton Sea Rerun part 1(w obd).xlsx

PP_2018-09-19 15-00-38 Salton Sea part 2_M01-M02(w obd) Processed.xlsx

PP_2018-09-19 15-00-38 Salton Sea part 2_M01-M02(w obd).xlsx

PP_2018-09-19 18-17-47 Palm Springs Town Driving_M1-M3(w obd) Processed.xlsx

PP_2018-09-19 18-17-47 Palm Springs Town Driving_M1-M3(w obd).xlsx

PP_2018-09-20 13-04-31 Palm Springs Experimentation 1_M01-M02(w obd) Processed.xlsx

PP_2018-09-20 13-04-31 Palm Springs Experimentation 1_M01-M02(w obd).xlsx

PP_2018-09-21 08-16-36 Drive Back to Oakland Leg 1_M1-M4(w obd) Processed.xlsx

PP_2018-09-21 08-16-36 Drive Back to Oakland Leg 1_M1-M4(w obd).xlsx

PP_2018-09-26 13-36-58 Drive to I5 and Ryer Island_M01-M02(w obd) Processed.xlsx

PP_2018-09-26 13-36-58 Drive to I5 and Ryer Island_M01-M02(w obd).xlsx

PP_2018-09-27 14-34-54 FTP Cruze Cold Start _M01-M02_with_OBD Processed.xlsx

PP_2018-09-27 14-34-54 FTP Cruze Cold Start _M01-M02_with_OBD.xlsx

PP_2018-09-27 15-55-29 HWFET_M01-M02_with_OBD Processed.xlsx

PP_2018-09-27 15-55-29 HWFET_M01-M02_with_OBD.xlsx

PP_2018-09-27 16-36-00 SCO3 Cruze_M01-M02_with_OBD Processed.xlsx

PP_2018-09-27 16-36-00 SCO3 Cruze_M01-M02_with_OBD.xlsx

PP_2018-09-28 07-54-44 Ryer Back to Oakland_M01-M02(w obd) Processed.xlsx

PP_2018-09-28 07-54-44 Ryer Back to Oakland_M01-M02(w obd).xlsx

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PP_2018-10-01 10-07-02 2015 Cruze Oakland 3 mi restarts SnG_M1-M4_with_OBD.xlsx

PP_2018-10-04 10-22-44 2015 Chevy Cruze RF to I5 South 70 mph cc_M1-M6_with_OBD Processed.xlsx

PP_2018-10-04 10-22-44 2015 Chevy Cruze RF to I5 South 70 mph cc_M1-M6_with_OBD.xlsx

PP_2018-10-04 13-32-22 2015 Cruze South I5 to RF 70 mph cc_M1-M4_with_OBD Processed.xlsx

PP_2018-10-04 13-32-22 2015 Cruze South I5 to RF 70 mph cc_M1-M4_with_OBD.xlsx

PP_2018-10-21 08-06-37 Drive to Palm Springs Cruze GDI_M01-M02(w obd) updated Processed.xlsx

PP_2018-10-21 08-06-37 Drive to Palm Springs Cruze GDI_M01-M02(w obd) updated.xlsx

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PP_2018-10-23 11-39-55 2015 Chevrolet Cruze GDI Salton Loop and constant grade_M01-M02(w obd) Processed.xlsx

PP_2018-10-23 11-39-55 2015 Chevrolet Cruze GDI Salton Loop and constant grade_M01-M02(w obd).xlsx

PP_2018-10-24 13-00-32 2015 Chevy Cruze GDI Salton Loop_M01-M02(w obd) Processed.xlsx

PP_2018-10-24 13-00-32 2015 Chevy Cruze GDI Salton Loop_M01-M02(w obd).xlsx

PP_2018-10-26 12-35-15 Chevy Cruze GDI 2015 Salton Sea Loop_M01-M02_with_OBD Processed.xlsx

PP_2018-10-26 12-35-15 Chevy Cruze GDI 2015 Salton Sea Loop_M01-M02_with_OBD.xlsx

PP_2018-10-27 12-18-20 2015 Cruze GDI Palm Springs Highways_M01-M02_with_OBD Processed.xlsx

PP_2018-10-27 12-18-20 2015 Cruze GDI Palm Springs Highways_M01-M02_with_OBD.xlsx

PP_2018-10-29 08-52-33 Drive from Palm Springs to Oakland 60 to 70 MPH I5_M01-M02(w obd) Processed.xlsx

PP_2018-10-29 08-52-33 Drive from Palm Springs to Oakland 60 to 70 MPH I5_M01-M02(w obd).xlsx

PP_2018-11-15 13-33-23 Chevy Cruze 2015 GDI in twn_M01-M02_with_OBD Processed.xlsx

PP_2018-11-15 13-33-23 Chevy Cruze 2015 GDI in twn_M01-M02_with_OBD.xlsx

PP_2018-11-16 11-10-17 2015 Cruze GDI Oakland in town_M1-M4_with_OBD Processed.xlsx

PP_2018-11-16 11-10-17 2015 Cruze GDI Oakland in town_M1-M4_with_OBD.xlsx

PP_2018-11-19 10-22-43 2015 Cruze GDI I5 south _M1-M4_with_OBD Processed.xlsx

PP_2018-11-19 10-22-43 2015 Cruze GDI I5 south _M1-M4_with_OBD.xlsx

PP_2018-11-26 10-35-17 2015 Cruze GDI RF to Manteca in twn n back_M1-M6_with_OBD Processed.xlsx

PP_2018-11-26 10-35-17 2015 Cruze GDI RF to Manteca in twn n back_M1-M6_with_OBD.xlsx

PP_2018-11-29 11-21-05 2015 Cruze DSL in twn Oakland_M1-M6_with_OBD Processed.xlsx

PP_2018-11-29 11-21-05 2015 Cruze DSL in twn Oakland_M1-M6_with_OBD.xlsx

PP_2018-12-05 13-57-01 2015 Cruze DSL Internal Blvd_M01-M02_with_OBD Processed.xlsx

PP_2018-12-05 13-57-01 2015 Cruze DSL Internal Blvd_M01-M02_with_OBD.xlsx

PP_2018-12-16 06-51-02 2015 Cruze DSL MN 30sF Highway tward Duluth_M01-M02_with_OBD Processed.xlsx

PP_2018-12-16 06-51-02 2015 Cruze DSL MN 30sF Highway tward Duluth_M01-M02_with_OBD.xlsx

PP_2018-12-17 06-09-35 2015 Cruze DSL MN 25_38F in twn St Paul_M01-M02_with_OBD Processed.xlsx

PP_2018-12-17 06-09-35 2015 Cruze DSL MN 25_38F in twn St Paul_M01-M02_with_OBD.xlsx

PP_2018-12-18 05-53-46 2015 Cruze DSL MN 29-45F to Duluth in twn SnG and Back_M01-M02_with_OBD Processed.xlsx

PP_2018-12-18 05-53-46 2015 Cruze DSL MN 29-45F to Duluth in twn SnG and Back_M01-M02_with_OBD.xlsx

PP_2018-12-20 05-54-07 2015 Cruze DSL MN 35F mix in twn and Highway_M01-M02_with_OBD Processed.xlsx

PP_2018-12-20 05-54-07 2015 Cruze DSL MN 35F mix in twn and Highway_M01-M02_with_OBD.xlsx

PP_2019-01-05 08-27-24 2015 Chevy Cruze DSL MN 42-47F Highway twd Fargo_M01-M02_with_OBD Processed.xlsx

PP_2019-01-05 08-27-24 2015 Chevy Cruze DSL MN 42-47F Highway twd Fargo_M01-M02_with_OBD.xlsx

PP_2019-01-06 08-25-26 2015 Cruze GDI MN 30-37F in twn n Highway_M01-M02_with_OBD.xlsx

PP_2019-01-06 08-25-26 2015 Cruze GDI MN 30-37F in twn n Highway_M01-M02_with_OBD Processed.xlsx

PP_2019-01-07 08-40-01 2015 Cruze GDI MN 40F in twn ST Paul_M01-M02_with_OBD Processed.xlsx

PP_2019-01-07 08-40-01 2015 Cruze GDI MN 40F in twn ST Paul_M01-M02_with_OBD.xlsx

PP_2019-01-08 08-14-01 2015 Cruze GDI MN 22-28F Highway twd Duluth_M01-M02_with_OBD Processed.xlsx

PP_2019-01-09 07-26-58 2015 Cruze DSL MN 5-15F 60-75mph Highway to Fargo_M01-M02_with_OBD Processed.xlsx

PP_2019-01-08 08-14-01 2015 Cruze GDI MN 22-28F Highway twd Duluth_M01-M02_with_OBD.xlsx

PP_2019-01-09 07-26-58 2015 Cruze DSL MN 5-15F 60-75mph Highway to Fargo_M01-M02_with_OBD.xlsx

PP_2019-01-10 07-11-19 2015 Cruze DSL MN 16-26F in twn SnG St Paul_M01-M02_with_OBD Processed.xlsx

PP_2019-01-11 07-30-49 2015 Cruze DSL MN 25-35F hw to Duluth in Twn and Back_M01-M02_with_OBD Processed.xlsx

PP_2019-01-10 07-11-19 2015 Cruze DSL MN 16-26F in twn SnG St Paul_M01-M02_with_OBD.xlsx

PP_2019-01-11 07-30-49 2015 Cruze DSL MN 25-35F hw to Duluth in Twn and Back_M01-M02_with_OBD.xlsx

PP_2019-01-12 11-11-20 2015 Cruze DSL MN 30s F in twn Stillwater_M01-M02 Processed.xlsx

PP_2019-01-12 11-11-20 2015 Cruze DSL MN 30s F in twn Stillwater_M01-M02_with_OBD.xlsx

PP_2019-02-09 09-23-51 2015 Chevy Cruze Diesel 0 to 10F MN Hwy and short town (w obd) Processed.xlsx

PP_2019-02-10 08-19-27 2015 Cruze Diesel 10 to 20 F Town and Hwy_M01-M02(w obd) Processed.xlsx

PP_2019-02-09 09-23-51 2015 Chevy Cruze Diesel 0 to 10F MN Hwy and short town (w obd).xlsx

PP_2019-02-10 08-19-27 2015 Cruze Diesel 10 to 20 F Town and Hwy_M01-M02(w obd).xlsx

PP_2019-02-11 07-57-16 2015 Cruze Diesel MN town 20-30F_M01-M02(w obd) Processed.xlsx

PP_2019-02-11 07-57-16 2015 Cruze Diesel MN town 20-30F_M01-M02(w obd).xlsx

PP_2019-02-12 10-26-51 2015 Cruze Diesel MN HWY 20 to 30 F_M01-M02(w obd) Processed.xlsx

PP_2019-02-12 10-26-51 2015 Cruze Diesel MN HWY 20 to 30 F_M01-M02(w obd).xlsx

PP_2019-02-13 07-59-13 2015 Chevrolet Cruze MN 10 to 20 F Town and HWY_M01-M02(w obd) Processed.xlsx

PP_2019-02-13 07-59-13 2015 Chevrolet Cruze MN 10 to 20 F Town and HWY_M01-M02(w obd).xlsx

PP_2019-02-14 07-11-38 2015 Chevrolet Cruze Diesel 25 to 17 F HWY and Town_M01-M02(w obd) Processed.xlsx

PP_2019-02-14 07-11-38 2015 Chevrolet Cruze Diesel 25 to 17 F HWY and Town_M01-M02(w obd).xlsx

PP_2019-02-24 06-49-33 2015 Cruze GDI MN 15 to 20F hwy and twn_M01-M02_with_OBD Processed.xlsx

PP_2019-02-24 06-49-33 2015 Cruze GDI MN 15 to 20F hwy and twn_M01-M02_with_OBD.xlsx

PP_2019-02-25 08-40-03 2015 Cruze GDI MN 1 to 5F in twn st paul and hwy_M01-M02_with_OBD Processed.xlsx

PP_2019-02-25 08-40-03 2015 Cruze GDI MN 1 to 5F in twn st paul and hwy_M01-M02_with_OBD.xlsx

PP_2019-02-26 08-57-35 2015 Cruze GDI MN 1 to 9F in twn st paul and hwy_M01-M02_with_OBD Processed.xlsx

PP_2019-02-26 08-57-35 2015 Cruze GDI MN 1 to 9F in twn st paul and hwy_M01-M02_with_OBD.xlsx

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GMCOUNTS000000001

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Bates Numbered Documents

Production Documents

Appendix C

ED_002826_00001297
ED_002826_00001299
ED_002826_00001955
ED_002826_00005675
ED_002826_00005676
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40 CFR § 86.158-00 "Supplemental Federal Test Procedures"

40 CFR § 86.159-08

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12 APPENDIX D: OVERVIEW OF DIESEL VEHICLE EMISSIONS

Plaintiffs' allegations in this case concern emissions of oxides of nitrogen (NO_x), which includes nitrogen dioxide (NO_2) and nitric oxide (NO).[425] NO_x is released into the air from the exhaust of motor vehicles due to the combustion of diesel and gasoline fuels.[426] NO_x is also released into the atmosphere from the burning of biomass, coal, oil, or natural gas in industrial processes and home heating.[427] Below I describe the air quality standards that regulate NO_x levels and other pollutants, emissions of NO_x from vehicles, and the technologies in diesel vehicles designed to reduce NO_x and other emissions.

12.1 Air Quality Standards that Regulate Emissions Levels

"The Clean Air Act requires EPA to set national *air quality standards* for common pollutants based solely on protecting public health and welfare. In addition, the Act requires states or EPA (depending on the program) to set *emissions standards* or limits for air pollution sources such as power plants, industrial facilities or motor vehicles. These emissions standards may be designed to control common pollutants, toxic pollutants, or greenhouse gas pollution."[428]

The allowable concentrations for six substances – ozone, NO_2, carbon monoxide (CO), sulfur dioxide (SO_2), particulate matter (PM)[429] and lead – known as Criteria Air Pollutants (CAPs)[430] are established by the United States Environmental Protection Agency (EPA) through the National Ambient Air Quality Standards (NAAQS). The EPA tracks CAP concentrations in the ambient air to identify both improvements and deterioration of ambient air quality.

California maintains its own air quality standards for CAPs, referred to as the California Ambient Air Quality Standards (CAAQS). Similar to the NAAQS, the CAAQS include separate standards for ozone, NO_2, CO, SO_2, PM, and lead. In addition to these six

425 *See* Smithers Report, ¶¶ 13-15, 18, and 20.

426 "Report on the Environment, Nitrogen Oxides Emissions." *Environmental Protection Agency*.

427 *Id.*

428 *See* "Clean Air Act Overview: Setting Emissions Standards Based on Technology Performance." *Environmental Protection Agency,* available at: https://www.epa.gov/clean-air-act-overview/setting-emissions-standards-based-technology-performance

429 The EPA regulates PM of two sizes: less than 10 microns in diameter (PM_{10}) and PM less than 2.5 microns in diameter ($PM_{2.5}$).

430 *See* "NAAQS Table," available at https://www.epa.gov/criteria-air-pollutants/naaqs-table, and "Environment and Contaminants: Criteria Air Pollutants," available at https://www.epa.gov/sites/production/files/2015-10/documents/ace3_criteria_air_pollutants.pdf.

substances, the CAAQS also regulates emissions for which there are no federal standards: visibility reducing particles, sulfates, hydrogen sulfide, and vinyl chloride.[431]

12.2 Emissions of NO_x from Vehicles and Light-Duty Diesel Vehicles

In order to help meet NAAQS, the EPA promulgated EPA Tier 2 standards.[432] The EPA Tier 2 standards established limits for NO_x and other emissions for passenger and light-duty vehicles. According to the EPA's 2014 National Emissions Inventory Data, motor vehicles (light-duty and heavy-duty) comprised approximately 35% of the annual total NO_x emissions in the United States in 2014.[433] Light-duty diesel vehicles comprised only about 1% of the annual total NO_x emissions in the United States, or approximately 4% of the on-road vehicles category.[434]

12.3 Other Vehicle Emissions Besides NO_x

Beyond NO_x, engine combustion byproducts include other emissions regulated by EPA Tier 2 standards such as $PM_{2.5}$, CO, non-methane hydrocarbon (NMHC)/non-methane organic gases (NMOG), and formaldehyde (HCHO). These are regulated under Tier 2 standards (which apply to the Subject Vehicles) by the EPA, and communicated to the consumer through a "smog" rating system[435] tied to the certification bin.[436] It is my understanding that both NO_x and NMOG can create smog.[437] Certain emissions that are relevant to diesel vehicle NO_x emissions are discussed further in the following sub-sections. Emissions standards relevant to the 2014-2015 Cruze are discussed further in Section 1 (Appendix E).

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431 *See* "California Ambient Air Quality Standards," available at https://ww2.arb.ca.gov/resources/california-ambient-air-quality-standards

432 "Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements; Final Rule," Federal Register, Vol. 65, No. 28, February 10, 2000, pp. 6703-6705.

433 *See* "Air Emissions Inventories: 2014 National Emissions Inventory (NEI) Data," available at https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data.

434 *Ibid*.

435 *See* "Green Vehicle Guide: Smog Rating," available at https://www.epa.gov/greenvehicles/smog-rating.

436 For example, the MY2015 Chevrolet Cruze diesel vehicle certified to Tier2-Bin5 had a smog rating of 5 and the MY2015 Chevrolet Cruze gasoline vehicle certified to a Tier2-Bin4 with more stringent limits for emissions had a smog rating of 6, as discussed in Section 6.1.2.

437 "Light Duty Vehicle Emissions." *Environmental Protection Agency,* available at: https://www.epa.gov/greenvehicles/light-duty-vehicle-emissions. Accessed June 5, 2020.

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12.3.1 Greenhouse Gas (GHG)

Internal combustion engines produce greenhouse gas (GHG) primarily in the form of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).[438,439] The most prevalent GHG is CO_2. The EPA has GHG standards and requires reporting of CO_2 emissions on a gram per mile basis on the vehicle's "Monroney sticker,"[440] a label required by law to be displayed on the window of all new vehicles sold in the United States.[441]

12.3.2 Ammonia

Although ammonia (NH_3) is not directly regulated by passenger vehicle emissions standards, ammonia is regulated by the EPA in other contexts.[442] Ammonia can be released through diesel vehicle after-treatment systems that control NO_x.[443] The corresponding ammonia emissions, which contribute to PM formation, are referred to as "ammonia slip." The EPA recommends that "NH_3 slip should be below 10 ppm."[444] Ammonia is also produced during catalytic reduction of NO_x by gasoline vehicles.[445]

12.4 "Clean Diesel" Technologies

Diesel vehicles were historically viewed as "dirty" and "noisy," which reduced the attractiveness of the diesel engine as a technology for use in passenger vehicles. Over the past 20 years, regulators have promoted and vehicle manufacturers have invested in improvements in engine and after-treatment technology and precise control of engine operating parameters for diesel engines. These improvements have refined diesel engines and enabled diesel vehicles to meet increasingly stringent emissions standards, which I describe fully in Appendix E.

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438 *See* "Green Vehicle Guide: Greenhouse Gas Emissions from a Typical Passenger Vehicle," available at https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle.

439 *See* "Carbon Pollution from Transportation," available at https://www.epa.gov/transportation-air-pollution-and-climate-change/carbon-pollution-transportation. *See also* "Green Vehicle Guide: Greenhouse Gas Rating," available at https://www.epa.gov/greenvehicles/greenhouse-gas-rating.

440 *See* Appendix E for further discussion of the Monroney sticker.

441 *See* "Revisions and Additions to Motor Vehicle Fuel Economy Label," *Federal Register*, Volume 76, No. 129, July 6, 2011 pp. 39478-39587.

442 Air Pollution control Technology Fact Sheet, EPA-452-F-03-032

443 Specifically, the Selective Catalytic Reduction system described in Section 12.4.2.1 below.

444 "Nonroad SCR Certification," *Environmental Protection Agency*, July 26, 2011 Webinar Presentation, available at https://www.epa.gov/sites/production/files/2016-09/documents/nrci-scr-web-conf.2011-07-25.pdf. Accessed June 6, 2020.

445 *See* Bishop, Gary A., Three Decades of On-Road Mobile Source Emissions Reductions in South Los Angeles. Journal of the Air & Waste Management Association, 69(8), 2019: 967-976.

The EPA started a Voluntary Diesel Retrofit Program in March of 2000,[446] which sparked a renewed interest in diesel engine technology in the United States. The program demonstrated how emission reduction technologies (in conjunction with cleaner fuels) could be retrofitted to the existing national fleet of school buses, delivery trucks, and transit buses. This was the inception of the EPA's National Clean Diesel Campaign, a program aimed at accelerating the adoption of advanced emissions-reduction technologies. Fueled by the initial success of the Voluntary Diesel Retrofit Program, the Energy Policy Act of 2005 provided the EPA with new grant and loan authority to promote clean diesel emission reduction programs. At the core of the clean diesel technology are three key components: (1) clean diesel fuel, (2) advanced engines, and (3) advanced emission controls.[447] Many automotive companies have used this suite of technologies and refer to them as "clean diesel" technologies. For example:

- Fiat Chrysler Automobiles introduced the Ram 1500 HFE truck 3.0L EcoDiesel V6 engine as incorporating "advanced clean diesel technology"[448]
- Cummins has referred to both legacy vehicles retrofit with its Longview technology and new small-truck engines as "Clean Diesels"[449]
- Mazda announced its new SKYACTIV-D 2.2 as a "clean diesel" engine[450]
- Mercedes-Benz advertises its BlueTEC models as "Clean Diesels"[451]
- Mitsubishi Motors Corporation identifies its 4N13 1.8-liter and 4N14 2.2-liter diesel engines as "Clean Diesel."[452]

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446 Perciasepe, Robert. "EPA Launches a Voluntary Program to Reduce Toxic Pollution from Existing Diesel Engines," *EPA Media Advisory*, March 2000, available at: https://archive.epa.gov/epapages/newsroom_archive/newsreleases/f83acde63cb7b29c852568a8004edad6.html.

447 *See* "Report to Congress: Highlights of the Diesel Emissions Reduction Program." EPA-420-R-09-006. August 2009, available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1005PP1.pdf.

448 *See* "RAM 1500," *RAM*. Archived on April 17, 2019. Available at: https://web.archive.org/web/20190417065803/https://www.ramtrucks.com/ecodiesel.html. Accessed on June 5, 2020

449 *See* "Cummins Displays Clean Diesels at Diesel Technology Forum Event," *Market Screener*, available at https://www marketscreener.com/CUMMINS-INC-12214/news/Cummins-Inc-Cummins-Displays-Clean-Diesels-at-Diesel-Technology-Forum-Event-335593/. Accessed on June 5, 2020

450 *See* "Mazda to Offer Diesel Engine in All-New Mazda CX-5 for North America from Second Half Of 2017," *Mazda*, available at https://insidemazda.mazdausa.com/press-release/mazda-offer-diesel-engine-new-mazda-cx-5. https://insidemazda.mazdausa.com/press-release/mazda-offer-diesel-engine-new-mazda-cx-5

451 *See* "BlueTEC Clean Diesel Cars and Vehicles," *Mercedes Benz*, available at https://www mbusa.com/mercedes/innovation/thinking_green/bluetec/src-... Accessed on June 5, 2020

452 *See* "Clean Diesel Engine," *Mitsubishi Motors*, available at http://www mitsubishi-motors.com/en/innovation/technology/library/diesel.html. Accessed on June 5, 2020

Generally speaking, "clean diesel" is used to describe a suite of vehicle technologies, vehicles that incorporate these technologies, and/or the use of ultra-low sulfur diesel (ULSD) fuel.[453, 454]

One important (and recent) advance in "clean diesel" engine technology was the development of the modern common rail injection system, which employs a shared, highly pressurized fuel rail to supply individual fuel injectors. This system allows for precisely controlled injection events independent of engine speed and load conditions, resulting in better fuel/air mixing to improve combustion efficiency, and reduced engine noise.[455] Another important technological step in the modernization of diesel engines was the introduction of the turbocharger, which increases the amount of air entering the cylinders during each intake stroke. With more air in the cylinders, the engine can inject more fuel and increase the engine's power output, or increase the air/fuel ratio. Using a turbocharger allows an engine of a given size to produce more power and/or run more efficiently.[456]

In addition to these technologies, the most important improvements to diesel vehicles have been the development of advanced electronic diesel control systems and exhaust after-treatment devices to control vehicle emissions. I describe these in detail below.

12.4.1 Advanced Electronic Diesel Control (EDC)

Modern vehicles are extremely complex and encounter a wide range of operating conditions and performance demands. In order to reach optimal operation, there is a need for precise control of the engine operating parameters, which requires control and adjustment of operating parameters such as the air/fuel ratio, idle speed, injection timing, and others based on the current operating conditions experienced by the vehicle. The Electronic Diesel Control (EDC), also referred to as the Engine Control Module (ECM) or Engine Control Unit (ECU), is a computer that sits at the center of this sophisticated system and balances the competing requirements of driver performance demands, emissions control, and engine protection and

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453 ULSD contains 97% less sulfur than untreated diesel fuel, and its use directly reduces the harmful emissions of diesel engines by more than 90%. While ULSD had been the standard for diesel fuel in Europe for many years, the changeover process in the U.S. began with a 2006 EPA mandate requiring that a portion of all highway-use diesel fuel produced or imported meet a 15 ppm maximum standard for sulfur content. The previous sulfur content standard had been 500 ppm, representing a 97% reduction in sulfur content. By the end of 2010, all highway-use diesel fuel was to be ULSD. *See* "Diesel Fuel Standards and Rulemakings," *Environmental Protection Agency*, available at https://www.epa.gov/diesel-fuel-standards/diesel-fuel-standards-and-rulemakings.

454 Furthermore, the introduction of cleaner fuel has allowed the development of a new generation of advanced diesel engines and emissions controls that would not be capable of operation with standard sulfur content fuel. *See* "What Is Clean Diesel?" *Diesel Technology Forum*, https://www.dieselforum.org/about-clean-diesel/what-is-clean-diesel.

455 Bauer, H. "Common Rail Accumulator Fuel-Injection System." (Ed.). Diesel-Engine Management Vol. 2. Society of Automotive Engineers, 1999.

456 Heywood, John B. *Internal Combustion Engine Fundamentals* Vol. 930, New York: McGraw-Hill, Chapter 6, 1988.

durability. The EDC takes in information about the state of the vehicle and the operating conditions and responds by altering operating parameters to optimize performance. Automakers have to navigate a complex design space which includes trade-offs between vehicle power and performance, fuel economy, emissions, comfort, utility, cost, and customer expectations.

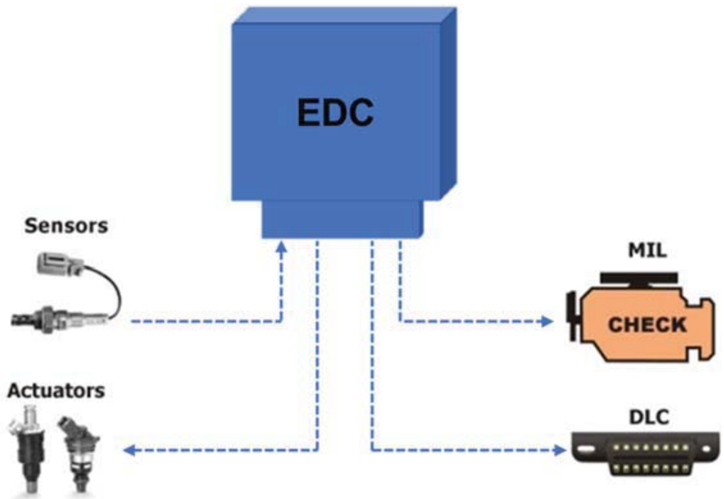

Figure D-1. EDC schematic inputs and controls[457]

While in service, a vehicle will experience a wide range of different driving and operating conditions. This variability creates a complicated and rapidly changing environment in which the vehicle must meet performance requirements while simultaneously controlling tailpipe emissions and protecting system components. The EDC is responsible for monitoring environmental conditions, the condition of the vehicle, sensor information, driver's demands, and emissions. From this information, the EDC must determine appropriate engine and after-treatment operating parameters. However, improving performance in one area can often mean sacrificing performance in another, and it is the job of the EDC to identify and account for these tradeoffs by adjusting operating parameters accordingly.[458]

Many of the performance trade-offs tied to engine operation are controlled by the EDC and may not be apparent to the driver. Vehicle fuel economy and emissions, including the production of NO_x and PM, can be affected by the operating parameters and are subject to tradeoffs. The components of an emissions control system do not always operate continuously. Selective operation of after-treatment and other emissions control strategies and performance compromises are necessary for a variety of reasons, including to protect vehicle components from damage, to ensure reliable operation during periods such as vehicle

457 Adapted from "What is OBD?" *OBD Solutions,* available at http://www.obdsol.com/knowledgebase/on-board-diagnostics/what-is-obd.

458 Vehicle performance can refer to a number of vehicle characteristics including, but not limited to, power, efficiency, emissions, drivability, and noise, vibration, and harshness (NVH).

start-up, and in certain emergency vehicles to prevent unwanted shut-down of emergency equipment.

During combustion, the ratio of oxygen to fuel in the cylinder (represented by the lambda value) influences the engine efficiency (fuel economy) and NO_x production. Diesel engines typically run "lean," with more oxygen than fuel present in the combustion chamber. Under leaner combustion conditions, the fuel is more completely combusted and the engine is more efficient. However, the presence of more oxygen in the combustion chamber at high temperatures generates more NO_x. Conversely, NO_x emissions can be decreased by running the engine "rich" with more fuel than oxygen in the combustion chambers. Rich conditions reduce NO_x emissions but increase particulates and reduce engine efficiency. How lean or rich the engine runs is controlled by the EDC.[459]

Another incentive to run the engine lean is to reduce the generation of PM. Diesel engines generate PM during combustion because air and fuel are mixed directly within the combustion chamber, resulting in less homogeneous mixing compared to non-direct injection systems. Direct injection leads to a heterogeneous combustion environment, so even though there is more oxygen than fuel on average, poor mixing still contributes to significant PM formation. Changing the air to fuel ratio can further affect PM formation in diesel engines.[460]

To control emissions, the EDC must either reduce engine production of a certain substance (such as NO_x) by changing operating parameters such as the air to fuel ratio, or control emissions through exhaust after-treatment to bring them down to the acceptable limit. As part of this effort, the EDC must manage the after-treatment systems. The development of On-Board Diagnostic (OBD) systems arose from the growing need to access various vehicle subsystems and monitor and regulate vehicle emissions. The OBD is often discussed as an independent system, but it is, in fact, reliant on the functions of the EDC. The EDC monitors and controls vehicle operation, which is how faults are detected. When the EDC detects abnormal operation, the OBD system alerts the driver by way of a Malfunction Indicator Light (MIL, a.k.a. the "check engine light"). The earliest versions of OBD systems often included a MIL that would illuminate to warn a vehicle operator of a possible malfunction with the operation of the engine, although the cause of the fault was typically not identified by this device. Modern versions of OBD systems (OBD-II) operate in a similar fashion and additionally store standardized diagnostic fault codes that provide basic information about the malfunction. I describe these systems below.

12.4.2 Modern Exhaust After-Treatment Systems

Even modern engines, although carefully engineered for efficiency and equipped with sophisticated engine control systems, cannot achieve perfect or complete combustion of fuel to CO_2 and water vapor and, therefore, generate incomplete combustion products. These

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459 *See* Heywood, John B. (1988). Internal Combustion Engine Fundamentals (Vol. 930). New York: McGraw-Hill, Chapter 10, 1988.

460 *Ibid.*

incomplete combustion products include PM, carbon monoxide, and unburned hydrocarbons. These engine emissions, along with NO_x that form when nitrogen and oxygen gases are mixed under the high temperature conditions of the combustion chamber, are byproducts of the internal combustion engine. The relative quantities of incomplete combustion products and nitrogen oxides are influenced by engine operating conditions. To some extent, emission of one or the other can be decreased by altering the air to fuel ratio in the combustion chambers. However, conditions that decrease engine emission of incomplete combustion products typically increase emission of nitrogen oxides; in some cases the physical and chemical principles restrict the ability of the engine alone to control emissions, which must be further mitigated by a series of exhaust after-treatment devices.

Exhaust after-treatment devices for diesel vehicles includes the following:

- Selective Catalytic Reduction (SCR) primarily for reducing NO_x emissions;
- Diesel Particulate Filter (DPF), primarily for reducing particulates and soot;[461] and
- Diesel Oxidation Catalyst (DOC), primarily for reducing oxidized organic compounds. [462]

12.4.2.1 Selective Catalytic Reduction (SCR)

In a SCR system, exhaust gases pass over a catalyst, and Diesel Exhaust Fluid (DEF) (a mixture of urea and water) is introduced into the exhaust stream to reduce the NO_x concentration in exhaust gases by converting it to nitrogen gas (N_2) and water (H_2O). [463, 464]DEF is a consumable that must be replenished at regular maintenance intervals by the user and has a limited shelf life.[465] On a vehicle, DEF is stored in a dedicated tank and is injected into the exhaust gases.

SCR systems were initially developed for stationary diesel engines, and had already demonstrated a significant reduction in NO_x emissions for this use. However, for light duty diesel vehicles, the EPA noted that, in order to achieve the relevant emissions standards, SCR technology needed to evolve to precisely meter the DEF such that sufficient emission

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461 Technical Bulletin: Diesel Particulate Filter General Information. EPA-420-F-10-029.

462 Technical Bulletin: Diesel Oxidation Catalyst General Information. EPA-420-F-10-031.

463 Bauer, H. (Ed.). “Combustion in the Diesel Engine.” Diesel-Engine Management (Vol. 2). Society of Automotive Engineers, 1999.

464 Guzella, Lino and Christopher Onder, “Introduction to Modeling and Control of Internal Combustion Engine Systems,” Springer Science & Business Media, 2004, pp. 137-146.

465 Peak BlueDEF spec sheet.

reduction would occur without excessive ammonia emissions.[466] If the DEF is not dosed correctly, use of SCR can also lead to "ammonia slip," which is the escape of ammonia through the SCR and the tailpipe.[467] Therefore, the effective functioning of the SCR also requires tradeoffs with other aspects of vehicle performance and emissions, particularly the management of ammonia slip. An example of a diesel after-treatment system that uses an SCR is presented below.

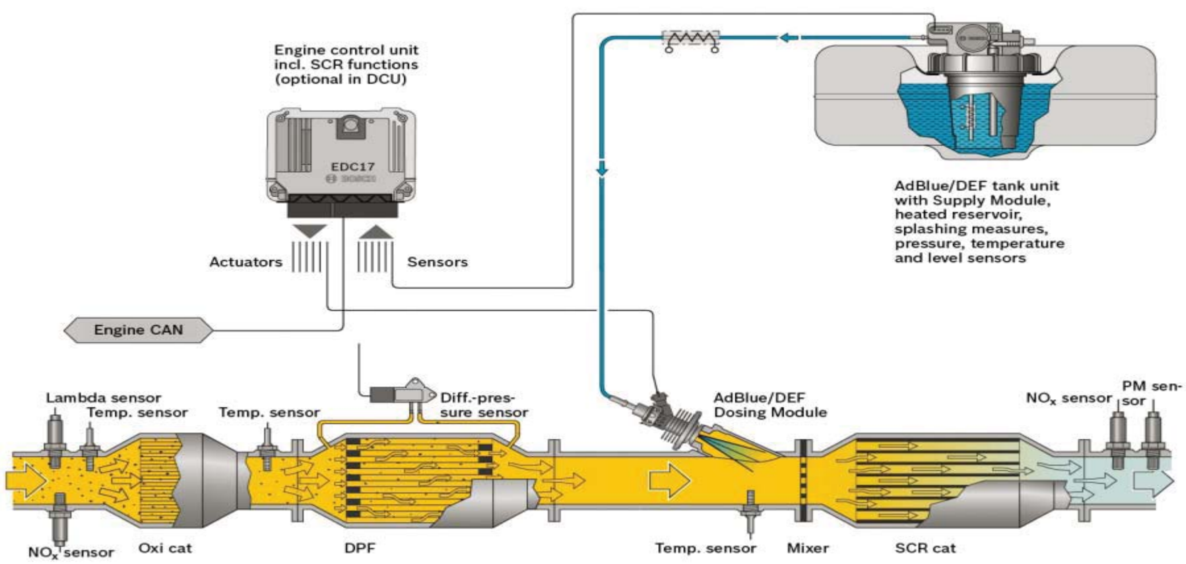

Figure D-2. Diesel engine exhaust after-treatment schematic showing the SCR.[468]

12.4.2.2 Diesel Particulate Filter (DPF)

In addition to NO_x reduction, diesel engine after-treatment systems include devices and methods to reduce the amount of PM emitted. Particulate traps, such as DPFs, enable light duty diesel vehicles to achieve 85-90% PM control or more, in turn leading to a substantial reduction in PM and virtually eliminating the black smoke historically associated with "dirty" diesel engines.[469]

The DPF collects particulates from the exhaust stream and stores them on a filter. DPFs require periodic regeneration at an appropriate interval, which effectively cleans the DPF of

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466 "The urea must be injected at very precise rates, which is difficult to achieve with an on-highway engine, because of widely varying engine operating conditions." *See* "Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements," Federal Register, Vol. 65, No. 28, February 10, 2000. p. 6728.

467 Sorrels, J. L., et al. "Selective Catalytic Reduction," Section 4 – NOx Controlsin *EPA Air Pollution Control Cost Manual*, 2019, pp. 19-20.

468 Figure adapted from GMCOUNTS000448249 at p. 5.

469 Technical Bulletin: Diesel Particulate Filter General Information. EPA-420-F-10-029.

accumulated PM.[470] This periodic regeneration is necessary for the proper functioning of the DPF, and for it to effectively keep emissions low, but the regeneration itself requires high exhaust temperatures. High exhaust temperatures are achieved with short periods of relatively high-speed or high-load operation, and through injection of diesel fuel into the exhaust stream, which can reduce fuel economy. Therefore, the effective functioning of the DPF also requires tradeoffs with other aspects of vehicle performance.[471]

12.4.2.3 Emissions Control through Exhaust Gas Recirculation (EGR)

Another approach for reducing emissions is to modify the engine operational conditions. Diesel engines can be equipped with exhaust gas recirculation (EGR).[472] EGR recycles a portion of exhaust gas back through the engine to reduce the combustion temperature, which changes the emissions profile to decrease NO_x production. Figure D-3, below, shows the path of exhaust gases in a compression-ignition engine that uses EGR.

470 DPFs have a relatively long regeneration cycle and can run for hundreds of miles between regenerations.

471 In another example of a tradeoff between DPF effectiveness and vehicle performance, particulate emissions can be controlled by engine combustion parameters, and are lower under lean combustion conditions where NO_x emissions are high. Moving to somewhat richer combustion conditions reduces NO_x but increases production of particulate matter.

472 *See, e.g.*, Jääskeläinen, H. and Magdi K. K. "Exhaust Gas Recirculation," *DieselNet*, available at https://dieselnet.com/tech/engine_egr.php.

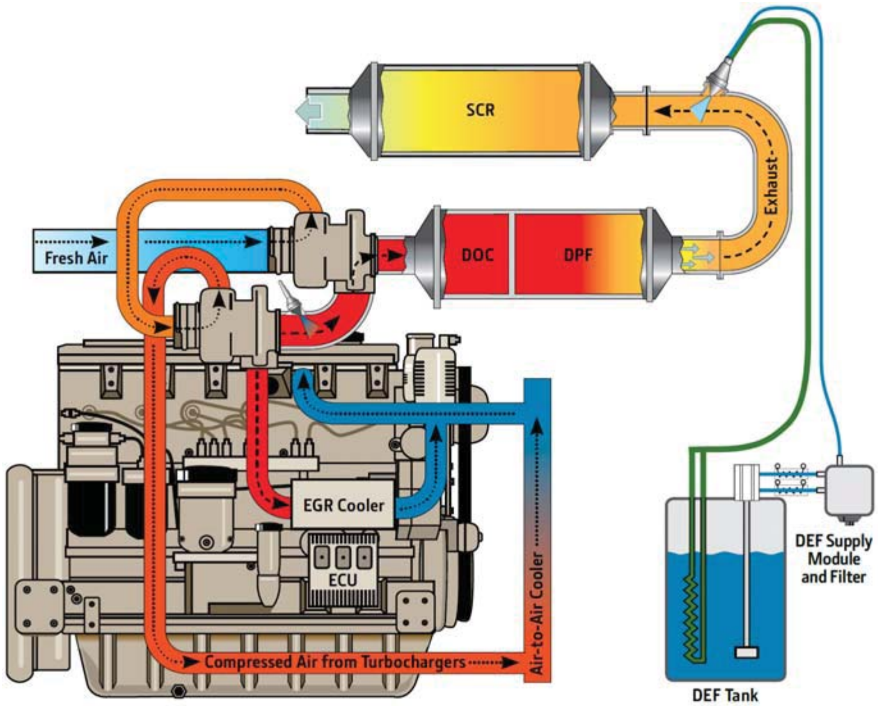

Figure D-3. Diesel engine schematic showing EGR system and the flow of exhaust gas.[473]

Increasing the amount of exhaust gas recirculated into the engine reduces the amount of fresh air in the combustion chambers. Because the exhaust gas has already experienced one combustion cycle, the amount of oxygen is significantly depleted compared to fresh air, which reduces the peak combustion temperature inside the cylinder. As a result of the lower peak combustion temperature, less NO_x is generated in the combustion chamber. However, use of EGR can also be detrimental to engine efficiency and to engine hardware because the exhaust gas carries PM back into the cylinders through the intake manifold, causing wear and increasing deposits. Furthermore, the use of EGR can also increase the amount of PM produced by the engine.[474]

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473 "Aftertreatment Solutions in a Stage V Landscape," John Deere diesel brochure, available at: https://www.deere.com/assets/pdfs/common/industries/engines-and-drivetrain/brochures/Aftertreatment_Solutions.pdf?sf94767743=1.[473] "Aftertreatment Solutions in a Stage V Landscape," John Deere diesel brochure, available at: https://www.deere.com/assets/pdfs/common/industries/engines-and-drivetrain/brochures/Aftertreatment_Solutions.pdf?sf94767743=1.

474 The EPA recognized as early as 1998 that EGR would likely be required for combustion ignition engines to meet emissions standards, despite the tradeoffs that EGR incurs. *See, e.g.*, EPA VPCD-98-13, October 15, 1998.

Additionally, greater control of NO_x, through higher amounts of EGR, can cause high particulate matter loading and, therefore, more frequent DPF regeneration events, which can reduce the life of the DPF and lead to early failures. This is another example of one of the many tradeoffs within the emissions control system of a diesel vehicle.

12.4.2.4 **Diesel Oxidation Catalyst (DOC)**

The DOC is used to mitigate tailpipe emissions of CO and hydrocarbons. Compared to the DPF and SCR units described above, the DOC is a relatively simple after-treatment device that is made of a precious metal-coated flow-through honeycomb structure. Unlike the SCR, no additional fluids are required for the DOC to function. However, most DOC units do rely on the use of ULSD fuel.[475]

475 "Technical Bulletin: Diesel Oxidation Catalyst General Information" *Environmental Protection Agency*, EPA-420-F-10-031.

13 APPENDIX E: OVERVIEW OF VEHICLE EMISSIONS STANDARDS AND TESTING

13.1 Vehicle Certification and Compliance Process

The U.S. Environmental Protection Agency (EPA) engages in vehicle certification and compliance activities prior to a vehicle's production, during production, and during a vehicle's useful life. I describe this process below.

13.1.1 Certificate of Conformity (CoC) Issuance

Emission standards for engines and vehicles sold in the United States are regulated by the EPA and the California Air Resources Board (CARB).[476] More specifically, the Clean Air Act requires that every new vehicle and new engine sold or imported into the U.S. be covered by a certificate of conformity, demonstrating that the vehicle conforms to all applicable U.S. emissions requirements.[477]

To obtain a CoC, a vehicle manufacturer submits an application for certification for a group of vehicles or engines with similar emission characteristics to the EPA.[478] The application includes detailed information on the engine design, production volume, manufacturer testing and deterioration data, and emission control equipment installed, along with disclosures on each AECD.[479] An AECD is defined as "any element of design which senses temperature, vehicle speed, engine RPM, transmission gear, manifold vacuum, or any other parameter for the purpose of activating, modulating, delaying, or deactivating the operation of any part of the emission control system."

Modulating, activating, and deactivating the operation of certain components of the emission control system has become more important with the introduction of more sophisticated emission control technologies. For example, in 1998 the EPA recognized that technologies like EGR (which were necessary to meet future, much stricter emission standards) will almost "certainly require modulation by an engine computer employing software and/or hardware that embodies a control strategy." Such modulations are expected and permitted, so long as they are disclosed to regulators and follow appropriate guidelines.

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476 As I discuss later in Appendix E, fuel economy standards are regulated by the National Highway Traffic Safety Administration (NHTSA), an agency within the Department of Transportation (DOT).

477 42 USC §7522(a)(1).

478 42 USC §7525. *See, also,* "2014-2017 Progress Report Vehicle Engine Compliance & Activities," *Environmental Protection Agency,* p. 29, available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100WKFC.pdf.

479 "2014-2017 Progress Report Vehicle Engine Compliance & Activities," *Environmental Protection Agency,* p. 29, available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100WKFC.pdf.

Additionally, the application for a CoC requires "[a] list of all auxiliary emission control devices (AECD) installed on any applicable vehicles, including a justification for each AECD, the parameters they sense and control, a detailed justification of each AECD that results in a reduction in effectiveness of the emission control system, and rationale for why it is not a defeat device as defined under § 86.1809."[480] There is no mention that the impact of AECDs "must be quantified as part of the certification process" as alleged by Mr. Smithers and the EPA Circular that Mr. Smithers cited at deposition does not mention the need for "quantification" of the AECD.[481]

A defeat device, as defined by the regulations and Mr. Smithers, is an AECD that "reduces the effectiveness of the emission control system under conditions which may reasonably be expected to be encountered in normal vehicle operation and use," **and also** (1) was not substantially included in the Federal Test Procedure, (2) was not justified for protection of the vehicle against damage or accident, or (3) went beyond the requirements of engine starting.[482]

There are additional requirements for vehicles with after-treatment systems that periodically regenerate, like the diesel particulate filter (DPF). Manufacturers must also provide sufficient documentation and data to evaluate the operation of the after-treatment devices and the proposed certification and testing procedure.[483]

As part of a vehicle's application review, experienced EPA engineers and scientists who review the application and may ask questions and seek additional information from the vehicle manufacturer in order to ensure that the vehicle complies with all applicable regulations.[484, 485] The information requested by the EPA may be collected through various methods including e-mails, meetings, and presentations.[486] The information requested by the EPA may be collected through various methods including e-mails, meetings, and presentations.

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480 40 CFR § 86.1844-01.(d)(11).

481 Smithers Report, ¶ 16.

482 40 CFR § 86.1803-01, 40 CFR § 86.1809-10.

483 40 CFR § 86.1305–2010

484 *See, e.g.,* Code of Federal Regulations, Part 86, Section 1844-01 - Information requirements: Application for certification and submittal of information upon request, available at https://www.law.cornell.edu/cfr/text/40/86.1844-01, ("Nothing in this section limits the Administrator's discretion to require the manufacturer to submit additional records not specifically required by this section.").

485 Bunker, Byron, "Certification Application Reporting Guidance," *Environmental Protection Agency,* November 24, 2014, p. 2, available at https://iaspub.epa.gov/otaqpub/display_file.jsp?docid=33582&flag=1.

486 Bunker, Byron, "Certification Application Reporting Guidance," *Environmental Protection Agency,* November 24, 2014, p. 2, available at https://iaspub.epa.gov/otaqpub/display_file.jsp?docid=33582&flag=1.

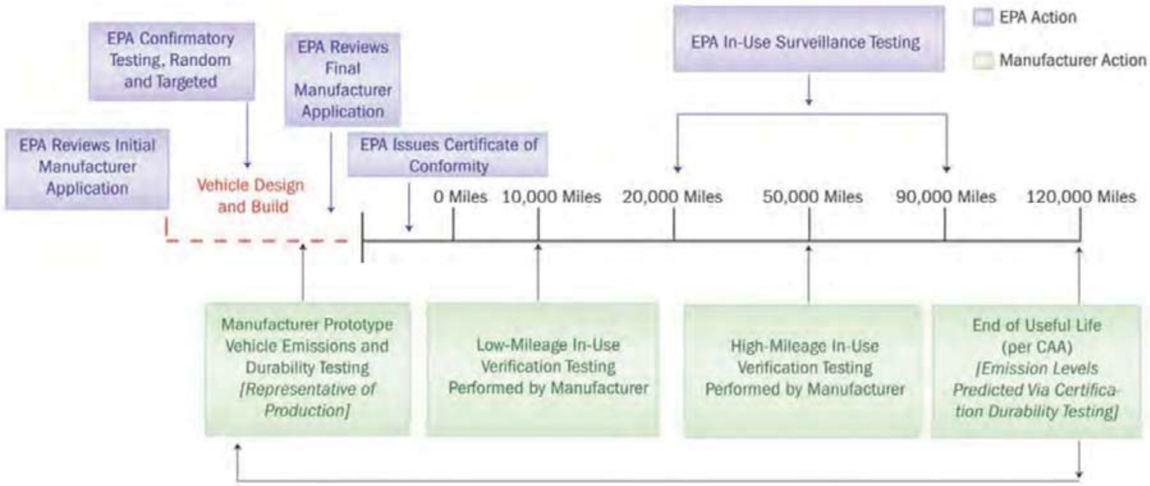

Figure E-1. The EPA has regulatory processes that cover multiple stages of a vehicle's useful life.

As shown in Figure E-1, the EPA also conducts confirmatory testing on a select number of vehicles or engines to verify the accuracy of the testing data submitted by the vehicle manufacturer as part of the certification process. In addition to confirmatory testing, the EPA undertakes compliance activities that occur during the vehicle or engine production stage. The purpose of such reviews is to confirm that vehicles coming off the production line are the same as the preproduction prototypes and match the same specifications set forth in the CoC.[487]

Based on its review of the final application, manufacturer testing data, and any requested confirmatory testing data, the EPA decides whether to issue a CoC. CoCs are issued on a model year (MY) basis, *i.e.,* a CoC is required for every model year of every engine family.[488]

13.1.2 Continued Oversight of CoC Compliance

Regulatory oversight continues after the EPA has issued a CoC. The EPA can continue to review (and revisit) certification decisions and seek additional information from manufacturers after a CoC has been issued. If the EPA ultimately determines that a vehicle manufacturer has provided inaccurate, incomplete, or falsified certification information, the EPA has the authority to revoke a CoC after it has been issued.[489] Furthermore, the EPA can void a CoC if

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487 "2014-2017 Progress Report Vehicle Engine Compliance & Activities," *Environmental Protection Agency*, p. 34-37, available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100WKFC.pdf.

488 "Certification Guidance for Engines Regulated Under: 40 CFR Part 86 (On-Highway Heavy-Duty Engines) and 40 CFR Part 89 (Nonroad CI Engines)", *Environmental Protection Agency*, p. 10, available at https://www.epa.gov/sites/production/files/2015-04/documents/compliance-nonroaddieselengines.pdf.

489 "Actions to Void Certificates for Vehicle and Engines," *Environmental Protection Agency*, available at https://www.epa.gov/recalls/actions-void-certificates-vehicle-and-engines.

the manufacturer does not comply with, or provide reasonable assistance to, the EPA in carrying out its authorized activities, which includes in-use testing (see below).[490]

The EPA requires in-use testing of vehicles that have been certified and are in customer service for some period of time to ensure compliance with applicable emissions standards.[491] There are two main types of in-use testing: the in-use verification program and the EPA surveillance program.

First, the EPA requires vehicle manufacturers to operate an in-use verification program (IUVP) to assess the emissions of in-use vehicles at two different points in the vehicle's useful life. The testing is split into low mileage vehicles with a minimum mileage of 10,000 miles[492] and high mileage vehicles with a minimum mileage of 50,000 miles.[493] The number of vehicles to be tested for each group depends on the total volume of vehicles sold. For manufacturers selling between 1-50,000 vehicles, in-use testing of two low mileage vehicles and four high mileage vehicles is required, although manufacturers selling fewer than 15,000 vehicles may be required to test fewer vehicles.[494] Test vehicles in both the high and low mileage groups are required to undergo FTP, US06, and HWFET standard dynamometer test cycles, during which vehicle emissions are measured.[495] Manufacturers are required to maintain and report testing records and results to the EPA on a regular basis.[496] The first IUVP must be completed on a low mileage vehicle one year after the end of production and the second must be a high mileage vehicle five years after the end of production. The results must be reported to the EPA, which are then used to identify any potential non-compliance.[497] In-use testing is conducted on dynamometers, not as on-road testing, and is not to be construed as on-road test limits set by EPA and CARB. As discussed below, on-road testing introduces variables that are difficult to control in a systematic way and is not to be confused with in-use testing.

490 *Ibid.*

491 "Overview of Certification and Compliance for Vehicles and Engines," *Environmental Protection Agency,* available at https://www.epa.gov/ve-certification/overview-certification-and-compliance-vehicles-and-engines.

492 40 CFR §86.1845-04(b)(2).

493 At least one vehicle in the high mileage test group must have a minimum odometer mileage of 105,000 miles or 75% of the full useful life mileage, whichever is lower. 40 CFR §86.1845-04(c)(2).

494 40 CFR §86.1845-04(b)(3) Table S04-07.

495 40 CFR §86.1845-04(b)(5); 40 CFR §86.1845-04(c)(5).

496 40 CFR §86.1847-01.

497 "2014-2017 Progress Report Vehicle & Engine Compliance Activities," *Environmental Protection Agency,* p. 56, available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100WKFC.pdf.

Further, the EPA conducts its own surveillance of in-use vehicles.[498] Similar to the IUVP tests, the EPA's testing is conducted on a dynamometer.[499] To evaluate the emissions performance of older vehicles, EPA borrows cars and small trucks from private owners and tests them at its National Vehicle and Fuel Emissions Laboratory (NVFEL) in Ann Arbor, Michigan. EPA tests about 150 customer-owned vehicles per year through this surveillance program. When a specific vehicle and model year is selected for surveillance, multiple vehicles are procured for testing. A single "failing" car may prompt further follow-up questions and investigations, but it does not prompt a recall or regulatory action.

Though it ultimately always relies on its own investigation, the EPA can also become aware of *potential* non-compliance by way of third party sources, including the public, the media, or researchers. For example, in May 2014, West Virginia University in collaboration with the International Council on Clean Transportation published results of its PEMS testing of light-duty vehicles.[500] Following this report, the EPA launched an investigation into its findings and ultimately issued a Notice of Violation (NOV) to Volkswagen (VW) in September 2015 finding that VW installed software in certain diesel vehicles that circumvented EPA emissions standards and constituted defeat devices.[501]

In connection with the Volkswagen case, the EPA has taken action to increase scrutiny of automobile manufacturers and to update its compliance and enforcement processes. For example, the EPA and CARB developed new testing procedures to assess whether vehicles, including those already in-use, contain defeat devices. The EPA issued a guidance letter to vehicle manufacturers in September 2015 stating that it "may test or require testing on any vehicle at a designated location, using driving cycles and conditions that may reasonably be expected to be encountered in normal operation and use, for the purposes of investigating a

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498 "2014-2017 Progress Report Vehicle & Engine Compliance Activities," *Environmental Protection Agency*, p. 52, available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100WKFC.pdf.

499 "EPA's In-Use Vehicle Emissions Surveillance Program," *Environmental Protection Agency*, p. 2, available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100YIP1.pdf.

500 Thompson Gregory J. *et al*., "In-Use Emissions Testing of Light-Duty Diesel Vehicles in the United States," Prepared for: International Council on Clean Transportation (ICCT), May 15, 2014, available at https://theicct.org/sites/default/files/publications/WVU_LDDV_in-use_ICCT_Report_Final_may2014.pdf. "EPA's notice of violation of the Clean Air Act to Volkswagen," *International Counsel on Clean Transportation*, September 18, 2015, available at https://theicct.org/sites/default/files/press-factsheet-combo_EPA-CARB-VW_20150918.pdf.

501 On the same day, CARB issued an In-Use Compliance letter to Volkswagen detailing a similar violation. Brooks, Phillip A., "Notice of Violation," *Environmental Protection Agency*, September 18, 2015, available at https://www.epa.gov/sites/production/files/2015-10/documents/vw-nov-caa-09-18-15.pdf. Hebert, A., "CARB Letter: Reference No. IUC-2015-007," *California Air Resources Board*, September 18, 2015.

potential defeat device."[502] The EPA further explained that "[s]uch testing can be expected in addition to the standard emissions test cycles."[503] A recent audit of the EPA's new compliance processes concluded that "the EPA demonstrated that its existing internal controls are effective."[504]

Notably, in the wake of the EPA's increased scrutiny, no NOV or other enforcement action has been issued to GM by either the EPA or CARB, including with respect to the Subject Vehicles. Mr. Smithers seems to acknowledge this increased scrutiny, when he states as part of his justification for the reliability and accuracy of PEMS systems, "[f]urthermore, both CARB and EPA make wide use of PEMS to evaluate vehicles for the presence of defeat devices."[505]

13.1.3 Defeat Devices

As discussed above, a defeat device is defined by the EPA as

> *"any element that reduces the effectiveness of the emissions control system under conditions which may reasonably be expected to be encountered in normal urban vehicle operation and use, unless:*
>
> *(1) Such conditions are substantially included in the Federal emission test procedure; or*
> *(2) The need for the AECD is justified in terms of protecting the vehicle against damage or accident;*
> *(3) The AECD does not go beyond the requirements of engine starting; or*
> *(4) The AECD applies only for emergency vehicles and the need is justified in terms of preventing the vehicle from losing speed, torque, or power due to abnormal conditions of the emission control system, or in terms of preventing such abnormal conditions from occurring, during operation related to emergency response. Examples of such abnormal conditions may include excessive exhaust backpressure from an overloaded particulate trap and running out of diesel exhaust fluid for engines that rely on urea-based selective catalytic reduction."*[506]

AECDs are allowed -- in fact, they are contemplated by -- the applicable regulations. While both a defeat device and an allowable, regulator-sanctioned AECD may take the form of

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502 Bunker, Byron, "SUBJECT: Conducted Confirmatory Testing," *Environmental Protection Agency*, September 25, 2015, available at https://19january2017snapshot.epa.gov/sites/production/files/2015-10/documents/cd-mfr-guid-ltr-2015-09-25.pdf.

503 *Ibid.*

504 "EPA Did Not Identify Volkswagen Emissions Cheating; Enhanced Controls Now Provide Reasonable Assurance of Fraud Detection" Environmental Protection Agency Office of Inspector General, Report No. 18-P-0181, p. 3.

505 Smithers Report, ¶83

506 40 CFR § 86.1803–01

software that "reduce[s] the effectiveness of the emissions control system" under certain conditions, one fundamental difference between a defeat device and an AECD is the disclosure to the EPA during certification. AECDs are disclosed as part of the certification process to ensure that any reduction in emissions control system function has an acceptable impact on overall vehicle emissions and has a well-justified purpose.[507] If an AECD is not disclosed during this process, and has certain characteristics, it is possible that this AECD may be considered a defeat device.

Should the regulators suspect that a vehicle contains a defeat device, they might request certain information or testing from the vehicle manufacturer to demonstrate the emissions performance characteristics of the vehicle over a range of driving conditions, on road or using the standardized test method.[508] The specific requirements for emissions performance vary based on the type of emission. For NO_x emissions, the regulation specifies the following provisions for vehicles under investigation for a possible defeat device:

> *"(b) The Administrator may test or require testing on any vehicle at a designated location, using driving cycles and conditions that may reasonably be expected to be encountered in normal operation and use, for the purposes of investigating a potential defeat device…*
>
> *(d) The following provisions apply for vehicle designs designated by the Administrator to be investigated for possible defeat devices:*
>
>> *(1) The manufacturer must show to the satisfaction of the Administrator that the vehicle design does not incorporate strategies that unnecessarily reduce emission control effectiveness exhibited during the Federal Test Procedure or Supplemental Federal Test Procedure (FTP or SFTP) when the vehicle is operated under conditions that may reasonably be expected to be encountered in normal operation and use.*
>>
>> *(2) The following information requirements apply:*
>>
>>> *(i) Upon request by the Administrator, the manufacturer must provide an explanation containing detailed information regarding test programs, engineering evaluations, design specifications, calibrations, on-board computer algorithms, and design strategies incorporated for operation both during and outside of the Federal emission test procedure.*

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507 Again, as stated above, the regulations do not require the impact to be "quantified," only that the AECD include information about the entry conditions, exit conditions, and engineering justification such that regulators can understand the impact and evaluate whether the vehicle can be certified.

508 40 CFR § 86.1809-10, available at https://www.govinfo.gov/content/pkg/CFR-2013-title40-vol20/pdf/CFR-2013-title40-vol20-sec86-1809-10.pdf

> *(ii) For purposes of investigations of possible cold temperature CO or cold temperature NMHC defeat devices under this paragraph (d), the manufacturer must provide an explanation to show, to the satisfaction of the Administrator, that CO emissions and NMHC emissions are reasonably controlled in reference to the linear guideline across the intermediate temperature range.*

> *(e) For each test group of Tier 2 LDV/LLDTs and HLDT/ MDPVs and interim non-Tier 2 LDV/LLDTs and HLDT/ MDPVs the manufacturer must submit, with the Part II certification application, an engineering evaluation demonstrating to the satisfaction of the Administrator that a discontinuity in emissions of non-methane organic gases, carbon monoxide, oxides of nitrogen and formaldehyde measured on the Federal Test Procedure (subpart B of this part) does not occur in the temperature range of 20 to 86 °F. For diesel vehicles, the engineering evaluation must also include particulate emissions."*[509]

Because vehicle emissions fluctuate in response to different driving conditions under normal circumstances (and as a result of sanctioned AECDs properly disclosed to the EPA), an increased level of vehicle emissions under a specific set of driving conditions is insufficient, in and of itself, to prove the existence of a defeat device. As described in Section 1 above, vehicle emissions are expected to vary in response to different driving conditions, and the identification of a possible defeat device typically requires in-depth understanding of emissions control systems as well as a careful analysis of test results that tie vehicle emissions to driving conditions both on-road and on standardized emission tests.

13.2 Vehicle Emissions Standards for Light-Duty Vehicles

The Clean Air Act Amendments of 1990 mandated development of federal standards for emissions in light-duty vehicles (LDV) and to date has been enacted in phases, namely,

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509 40 CFR § 86.1809-10 and 40 CFR § 86.1809-12, "Prohibition of defeat devices," available at https://www.govinfo.gov/content/pkg/CFR-2013-title40-vol20/pdf/CFR-2013-title40-vol20-sec86-1809-10.pdf and https://www.govinfo.gov/content/pkg/CFR-2013-title40-vol20/pdf/CFR-2013-title40-vol20-sec86-1809-12.pdf.

Tier 0,[510] Tier 1,[511] Tier 2,[512,513] and Tier 3.[514] Each Tier is adopted after successful implementation of the prior set of standards. Below I describe the relevant emissions standards and summarize the standards and thresholds specific to Tier 2 NO_x emissions standards, the Tier applicable to the Subject Vehicles. I also briefly describe cold temperature emissions standards, and why they are not relevant to NO_x emissions.

Tier 1 standards were introduced between model years 1994 and 1997, and applied to LDVs of less than 8,500 lbs. gross vehicle weight rating (GVWR) through model year 2003 (Table E-1). Tier 2 standards, phased in between model years 2004 and 2009, extended the applicability to medium-duty passenger vehicles (MDPV) with GVWR between 8,500 and 10,000 lbs. Tier 3 regulations extend the emission standards for chassis-certified heavy-duty vehicles up to 14,000 lbs. (Class 2b and Class 3), and are being phased in between model years 2017 and 2025.

Each new vehicle emission standard has required significant reductions in hydrocarbon (HC), carbon monoxide (CO), and nitrogen oxide (NO_x) emissions relative to the preceding standards' limits. In transitioning to a new standard, there can also be changes to the way a class of emissions is measured or grouped under the program's limits. For example, Tier 2 standards list separate limits for emissions of hydrocarbons (Non-Methane Organic Gases, or NMOG) and nitrogen oxides, while under Tier 3 the two types of substances are grouped together with a single limit (NMOG + NO_x). Several factors influence this type of change. For instance, in the case of combining NMOG and NO_x in the transition from Tier 2 to Tier 3, combining the limits provides vehicle manufacturers flexibility in the strategies they use to meet the new limit.[515]

510 Light-Duty Vehicles and Light-Duty Trucks: Tier 0, Tier 1, National Low Emission Vehicle (NLEV), and Clean Fuel Vehicle (CFV) Exhaust Emission Standards *Environmental Protection Agency*, EPA-420-B-16-010, March 2016. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100O9ZP.pdf.

511 Light-Duty Vehicles and Light-Duty Trucks: Tier 1 and National Low Emission Vehicle (NLEV) Supplemental Federal Test Procedure Exhaust Emission Standards. EPA -420-B-16-011. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100O9ZR.pdf

512 Light-Duty Vehicles, Light-Duty Trucks, and Medium-Duty Passenger Vehicles: Tier 2 Exhaust Emission Standards and Implementation Schedule. EPA-420-B-16-015. Available at https://nepis.epa.gov/Exe/ZyPDF.cgi/P100O9ZW.PDF?Dockey=P100O9ZW.PDF.

513 Light-Duty Vehicles, Light-Duty Trucks, and Medium-Duty Passenger Vehicles: Tier 2 and Interim Non-Tier 2 Supplemental Federal Test Procedure (SFTP) Exhaust Emission Standards. EPA-420-B-16-013. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100O9ZU.pdf

514 "Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards". In 40 CFR Parts 79, 80, 85, 86, 600, 1036, 1037, 1039, 1042, 1048, 1054, 1065, and 1066 edited by Environmental Protection Agency (EPA), 2014. EPA-420-R-14-005.

515 LEV III and Tier 3 Exhaust Emission Control Technologies for Light-Duty Gasoline Vehicles. Manufacturers of Emission Controls Association, April 2013, p. 8-11.

Table E-1. NO_x emissions limits through Tier 0 and Tier 1 for light duty vehicles (LDVs).[516]

Org	Vehicle Type	Tier	NOx Emission Limit at 50,000 Miles [g/mi]	NOx Emission Limit at 120,000 Miles [g/mi] (100,000 Miles for all 420-B-16 Docs)	Model Years Covered	EPA Document Source
Federal	LDV – All Fuels	0	1	NA	1981 - 1993	EPA-420-B-16-010
Federal	LDV – Gasoline Fueled	1	0.4	0.6	1994 - 1999	EPA-420-B-16-010
Federal	LDV – Diesel Fueled	1	1	1.25	1994-2003	EPA-420-B-16-010

516 "Light-Duty Vehicles and Light-Duty Trucks: Tier 0, Tier 1, National Low Emission Vehicle (NLEV), and Clean Fuel Vehicle (CFV) Exhaust Emission Standards" Environmental Protection Agency, EPA-420-B-16-010, March 2016. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100O9ZP.pdf.

EPA United States Environmental Protection Agency

Office of Transportation and Air Quality
EPA-420-B-16-015
March 2016

Light-Duty Vehicles, Light-Duty Trucks, and Medium-Duty Passenger Vehicles: Tier 2 Exhaust Emission Standards and Implementation Schedule

	Standard	Emission Limits at 50,000 miles					Emission Limits at Full Useful Life (120,000 miles) [a]				
		NOx (g/mi)	NMOG (g/mi)	CO (g/mi)	PM (g/mi)	HCHO (g/mi)	NOx (g/mi)	NMOG (g/mi)	CO (g/mi)	PM (g/mi)	HCHO (g/mi)
Federal	Bin 1	-	-	-	-	-	0	0	0	0	0
	Bin 2	-	-	-	-	-	0.02	0.01	2.1	0.01	0.004
	Bin 3	-	-	-	-	-	0.03	0.055	2.1	0.01	0.011
	Bin 4	-	-	-	-	-	0.04	0.07	2.1	0.01	0.011
	Bin 5	0.05	0.075	3.4	-	0.015	0.07	0.09	4.2	0.01	0.018
	Bin 6	0.08	0.075	3.4	-	0.015	0.1	0.09	4.2	0.01	0.018
	Bin 7	0.11	0.075	3.4	-	0.015	0.15	0.09	4.2	0.02	0.018
	Bin 8	0.14	0.100 / 0.125 [c]	3.4	-	0.015	0.2	0.125 / 0.156	4.2	0.02	0.018
	Bin 9 [b]	0.2	0.075 / 0.140	3.4	-	0.015	0.3	0.090 / 0.180	4.2	0.06	0.018
	Bin 10 [b]	0.4	0.125 / 0.160	3.4 / 4.4	-	0.015 / 0.018	0.6	0.156 / 0.230	4.2 / 6.4	0.08	0.018 / 0.027
	Bin 11 [b]	0.6	0.195	5	-	0.022	0.9	0.28	7.3	0.12	0.032

Notes:

Tests Covered: Federal Test Procedure (FTP), cold carbon monoxide (CO), highway, and idle

Model Year: 2004

a In lieu of intermediate useful life standards (50,000 miles) or to gain additional nitrogen oxides credit, manufacturers may optionally certify to the Tier 2 exhaust emission standards with a useful life of 150,000 miles.

b Bins 9-11 expire in 2006 for light-duty vehicles and light light-duty trucks and 2008 for heavy light-duty trucks and medium-duty passenger vehicles.

c Pollutants with two numbers have a separate certification standard (1st number) and in-use standard (2nd number).

Figure E-2. LDV, LDT, and MDPV Tier 2 exhaust emission standards.[517]

The Tier 2 emission standards are organized based on stringency into different certification levels. The standard calls for a fleet average NO_x limit of 0.07 g/mi following the implementation schedule indicated in Figure E-2.

517 Light-Duty Vehicles, Light-Duty Trucks, and Medium-Duty Passenger Vehicles: Tier 2 Exhaust Emission Standards and Implementation Schedule. EPA-420-B-16-015, available at https://nepis.epa.gov/Exe/ZyPDF.cgi/P100O9ZW.PDF?Dockey=P100O9ZW.PDF.

Implementation Schedule

	Vehicle Category	NOx avg. / cap (g/mi) [a]	Model Year						
			2004	2005	2006	2007	2008	2009	2010
Federal	LDV, LLDT	0.3 / -	75%	50%	25%	0%	-	-	-
		0.07 / -	25%	50%	75%	0%	-	-	-
		0.07 / 0.2	-	-	-	100%	100%	100%	100%
	HLDT, MDPV	- / 0.6	75%	50%	25%	0%	-	-	-
		0.02 / -	25%	50%	75%	100%	50%	0%	-
		0.07 / -	-	-	-	-	50%	0%	-
		0.07 / 0.2	-	-	-	-	-	100%	100%

Notes:

a At full useful life (120,000 miles).

Code of Federal Regulations (CFR) citations:

- 40 CFR 86 Subpart S

Figure E-3. Tier 2 implementation schedule.[518]

Under the Tier 2 standards, manufacturers were allowed to certify any given vehicle into any of several different "certification bins," each of which had different emissions limits, as long as the fleet average NO_x limit was in compliance with the implementation schedule presented above. From 2007 on, 100% of the fleet average was required to comply with the 0.07 g/mi NO_x limit. For instance, bin 5 has a NO_x limit of 0.07 g/mi, which is equal to the fleet average NOx standard. Therefore, NO_x emissions from vehicles certified to bins higher than bin 5 must be offset by selling a sufficient number of vehicles certified to bins lower than bin 5.

As discussed in Figure E-2, exhaust emission standards for intermediate useful life are applicable for five years or 50,000 miles, whichever occurs first. The full useful life period for LDVs and light-duty trucks (LDTs) was extended to 120,000 miles or ten years, whichever occurs first. Manufacturers could optionally certify their vehicles to the Tier 2 exhaust emission standards for 150,000 miles or 15 years to gain NO_x credits or to opt out of intermediate life standards.

LDVs and LDTs are also required to meet the requirements of supplemental federal test procedure exhaust emission standards. SFTP cycles include the US06 and SC03 for 4,000 mile and full useful life cycles, in addition to FTP requirements. The 4,000 mile SFTP standards for emissions are provided in the table shown in Figure E-4. Full useful life SFTP standards are calculated based on the formula and calculations presented in Figure E-5.

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518 Light-Duty Vehicles, Light-Duty Trucks, and Medium-Duty Passenger Vehicles: Tier 2 Exhaust Emission Standards and Implementation Schedule. EPA-420-B-16-015, available at https://nepis.epa.gov/Exe/ZyPDF.cgi/P100O9ZW.PDF?Dockey=P100O9ZW.PDF.

United States Environmental Protection Agency

Office of Transportation and Air Quality
EPA-420-B-16-013
March 2016

Light-Duty Vehicles, Light-Duty Trucks, and Medium-Duty Passenger Vehicles: Tier 2 and Interim Non-Tier 2 Supplemental Federal Test Procedure (SFTP) Exhaust Emission Standards

	Vehicle Type	4,000 Miles			
		US06 TEST		SC03 TEST	
		NMHC + NOx (g/mi)	CO (g/mi)	NMHC + NOx (g/mi)	CO (g/mi)
Federal [a]	LDV / LDT1	0.14	8.0	0.20	2.7
	LDT2	0.25	10.5	0.27	3.5
	LDT3	0.40	10.5	0.31	3.5
	LDT4	0.60	11.8	0.44	4.0

Notes:

a Manufacturers must calculate their applicable full useful life Supplemental Federal Test Procedure standards for non-methane hydrocarbon plus nitrogen oxides, particulate matter, and carbon monoxide (CO), if using the weighted CO standard. If not using the weighted CO standard, manufacturers may use the full useful life stand-alone Tier 1 standards for US06 and SC03.

Code of Federal Regulations (CFR) citations:

- 40 CFR 86 Subpart S

Figure E-4. Table showing 4,000 mile SFTP standards in g/mi, for Tier 2 LDVs and LDTs.[519]

519 Light-Duty Vehicles, Light-Duty Trucks, and Medium-Duty Passenger Vehicles: Tier 2 and Interim Non-Tier 2 Supplemental Federal Test Procedure (SFTP) Exhaust Emission Standards. EPA-420-B-16-013, available at https://nepis.epa.gov/Exe/ZyPDF.cgi/P100O9ZU.PDF?Dockey=P100O9ZU.PDF.

SFTP Standard = SFTP Standard$_1$−[0.35 × (FTP Standard$_1$−Current FTP Standard)]

Where:

SFTP Standard = Applicable full life weighted SFTP standard for NMHC + NO_X, PM or CO. The NMHC + NO_X and PM standards must be rounded to two decimal places and the CO standard must be rounded to one decimal place.

SFTP Standard$_1$ = Applicable full life Tier 1 SFTP standard for NMHC + NO_X or CO from Table S04-5. For PM only, use FTP Standard$_1$ for SFTP Standard$_1$.

FTP Standard$_1$ = Applicable full life Tier 1 FTP standard from Table S04-6 in this paragraph (f). For the Tier 1 NMHC + NO_X standard, add the applicable NMHC and NOx standards.

Current FTP Standard = Applicable full life FTP standard from Table S04-1 in paragraph (c) of this section. For the current NMHC + NO_X standard, add the NMOG and NO_X standards from the applicable bin.

TABLE S04-5—TIER 1 FULL USEFUL LIFE SFTP STANDARDS

Vehicle category	NMHC + NO_X (weighted g/mi)[a c]	CO (g/mi)[b c]		
		US06	SC03	Weighted
LDV/LDT1	0.91 (0.65)	11.1 (9.0)	3.7 (3.0)	4.2 (3.4)
LDT2	1.37 (1.02)	14.6 (11.6)	4.9 (3.9)	5.5 (4.4)
LDT3	1.44	16.9	5.6	6.4
LDT4	2.09	19.3	6.4	7.3

[a]Weighting for NMHC + NO_X and optional weighting for CO is 0.35x(FTP) + 0.28x(US06) + 0.37x(SC03).

[b]CO standards are stand alone for US06 and SC03 with option for a weighted standard.

[c]Intermediate life standards are shown in parentheses for diesel LDV/LLDTs opting to calculate intermediate life SFTP standards in lieu of 4,000 mile SFTP standards as permitted under paragraph (f)(6) of this section.

TABLE S04-6—TIER 1 FULL USEFUL LIFE FTP STANDARDS (G/MI)

Vehicle category	NMHC[a]	NO_X[a]	CO[a]	PM
LDV/LDT1	0.31 (0.25)	0.6 (0.4)	4.2 (3.4)	0.10
LDT2	0.40 (0.32)	0.97(0.7)	5.5 (4.4)	0.10
LDT3	0.46	0.98	6.4	0.10
LDT4	0.56	1.53	7.3	0.12

[a]Intermediate life standards are shown in parentheses for diesel LDV/LLDTs opting to calculate intermediate life SFTP standards in lieu of 4,000 mile SFTP standards as permitted under paragraph (f)(6)of this section.

Figure E-5. Full useful life SFTP standards.[520]

520 40 CFR § 86.1811–04 "Emission standards for light-duty vehicles, light-duty trucks and medium-duty passenger vehicles."

13.2.1 Subject Vehicle NO_x Emissions Limits

The Subject Vehicles were certified to Tier 2 Bin 5 emissions standards.[521] Table E-2 below presents a summary of the NO_x and NMOG emissions standards (where applicable) used by the EPA in certifying Tier 2 Bin 5 vehicle like the Subject Vehicles, expressed in grams per mile. These standards are unique to each test cycle and the conditions associated with each test cycle. Moreover, and as described above, these standards represent emissions thresholds that must be achieved on *average* over the entire test cycle. None of the regulatory standards applicable to light-duty vehicles specify a “shall not exceed” or absolute maximum emissions level for any given moment of a test cycle, nor do the regulations specify thresholds for a given segment of a test cycle. Notably, the EPA requirements for Tier 2 do not include emissions standards or testing procedures or requirements to evaluate light-duty vehicles emissions using PEMS equipment and the only method used by the EPA to establish emissions standards is laboratory dynamometer testing.

The standards for the SFTP test cycle (US06 and SC03 components) are based on NMOG +NO_x emissions. Typically, diesel vehicles such as the Subject Vehicles emit very low levels of NMOG and therefore emissions standards are often effectively NO_x levels. Put differently, the majority of the emissions measured in the NMOG +NO_x emission standard for the SFTP test cycles are NO_x emissions for diesels vehicles.[522]

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521 GMCOUNTS000050908, GMCOUNTS000220918.

522 As stated above in Section XX, this is not true of gasoline vehicles.

Table E-2. Tier 2 Bin 5 Emission Standards (g/mile).[523]

Test Procedure	Temperature	NMOG	NO_x	NMOG +NO_x
FTP@150k miles	68-86°F	0.09	0.07	-
SC03@4k miles	95°F	-	-	0.20
US06@4k miles	68-86°F	-	-	0.14
HWFET[524]@150k miles	68-86°F	-	0.09	-
SFTP@150k miles	68-95°F	-	-	0.65

The higher emission standards shown in Table E-2 for the SC03, USO6, and HWFET test cycles relative to the FTP emission standard reflect the more difficult testing conditions associated with these tests. In other words, the fact that different certification tests have different applicable standards (*i.e.,* that that SC03 and US06 cycles with higher engine loads also have higher allowable emissions standards), suggests that the EPA therefore *expects* increased emissions under these conditions.

13.2.2 Cold Temperature Emission Standards

As presented in Table E-2 above, the FTP, US06, and HWFET tests are all performed within a specified ambient temperature range of 68°F (20°C) to 86°F (30°C). A separate standard for cold temperature testing exists and is performed at 20°F (-7°C), but it applies to CO emissions only. The regulators have not set any specific emissions standards for NO_x (or NMOG or PM) that are associated with cold temperature conditions.

The Tier 2 cold temperature CO emission standard applicable to light-duty vehicles like the Subject Vehicles is numerically the same as the previous Tier 1 and National Low Emission

523 Light-Duty Vehicles, Light-Duty Trucks, and Medium-Duty Passenger Vehicles: Tier 2 Exhaust Emission Standards and Implementation Schedule. EPA-420-B-16-015, available at https://nepis.epa.gov/Exe/ZyPDF.cgi/P100O9ZW.PDF?Dockey=P100O9ZW.PDF. Light-Duty Vehicles, Light-Duty Trucks, and Medium-Duty Passenger Vehicles: Tier 2 and Interim Non-Tier 2 Supplemental Federal Test Procedure (SFTP) Exhaust Emission Standards. EPA-420-B-16-013, available at https://nepis.epa.gov/Exe/ZyPDF.cgi/P100O9ZU.PDF?Dockey=P100O9ZU.PDF. 40 CFR § 86.1811-04.

524 The EPA stipulated in the Tier 2 emissions regulations applicable to light duty vehicles for the HWFET test cycle that NO_x emissions be within the limits described as follows: "The maximum projected NO_x emissions measured on the federal Highway Fuel Economy Test in 40 CFR part 600, subpart B, must not be greater than 1.33 times the applicable FTP NO_x standard to which the manufacturer certifies the test group. Both the projected emissions and the product of the NO_x standard and 1.33 must be rounded to the nearest 0.01 g/mi before being compared." This implies a HWFET NO_x emission standard of 0.094 grams per mile for Tier 2 Bin 5 vehicles. *See* 40 CFR § 86.1811-04.

Vehicle (NLEV) emission standards of 10.0 g/mi, measured at 20 °F (-7 °C).[525] In addition to maintaining the 10.0g/mi CO level as part of its Tier 2 standards, the EPA also eliminated the 50°F (10°C) CO emission standards from the NLEV program and did not add other emissions standards.[526]

While the EPA did not set NO_x emissions standards for low temperature conditions, the EPA *does* consider low temperature emissions as part of their evaluation of potential defeat devices. In its code regarding "prohibition of defeat devices," the EPA requires vehicle manufacturers to submit an evaluation that "a discontinuity in emissions of […] oxides of nitrogen […] does not occur in the temperature range of 20 to 86 degrees F" (*i.e.*, through the temperature associated with the cold temperature CO emissions standard).[527]

An explanation of what constitutes a "discontinuity" was not provided by the EPA, but, given that emission standards other than CO are not listed in the Tier 2 emissions regulation and that GM's certification data for both the gasoline and diesel Cruze vehicles – which was shared with, and reviewed by, regulators at EPA – shows increases in regulated emissions when moving from warm to cold conditions, this implies that emissions increases at cold temperatures have been accepted by the EPA.[528] In other words, the regulations reflect an understanding that emissions controls do not operate at optimal levels at cold temperatures and emissions are therefore expected to be higher when driven under these conditions.

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525 "Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements; Final Rule," Federal Register, Vol. 65, No. 28, February 10, 2000, p. 6799. Tier 1 standard: "Light-Duty Vehicles and Light-Duty Trucks: Tier 0, Tier 1, National Low Emission Vehicle (NLEV), and Clean Fuel Vehicle (CFV) Exhaust Emission Standards," EPA-420-B-16-010, March 2016. Available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100O9ZP.pdf

526 "Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements; Final Rule," Federal Register, Vol. 65, No. 28, February 10 2000, p. 6799.

527 40 CFR § 86.1809-01. ("Prohibition of defeat devices. For each test group of Tier 2 LDV/LLDTs and HLDT/MDPVs and interim non-Tier 2 LDV/LLDTs and HLDT/MDPVs the manufacturer must submit, with the Part II certification application, an engineering evaluation demonstrating to the satisfaction of the Administrator that a discontinuity in emissions of non-methane organic gases, carbon monoxide, oxides of nitrogen and formaldehyde measured on the Federal Test Procedure (subpart B of this part) does not occur in the temperature range of 20 to 86 degrees F. For diesel vehicles, the engineering evaluation must also include particulate emissions").

528 [redacted]

13.3 Vehicle Emissions Testing Protocols

The EPA specifies detailed protocols for the emissions testing conducted as part of the certification and compliance process.[529] Testing to determine whether a vehicle complies with emissions standards is conducted in a carefully controlled laboratory setting using set driving schedules on a dynamometer. Below I describe the laboratory protocols required for testing. I also describe the specific test-driving schedules required by the EPA and the reasons why in-use testing is not used to certify compliance with federal emissions standards.

13.3.1 Laboratory Protocols for Vehicle Emissions Testing Procedures

Certification dynamometer chassis test procedures are inherently prescriptive and require scrupulous vehicle, fuel, and test equipment preparation. This is to ensure accuracy and repeatability of test results and to compare vehicles of different makes and specifications. CFR Part 86 Subpart B sets forth the test procedures for emission testing. The information provided in this section is a partial summary of the testing protocol as it applies to diesel vehicles, and is not to be taken as a complete recitation of the entire procedure.

Ambient temperature levels encountered by the test vehicle shall be not less than 68 °F (20 °C) nor more than 86 °F (30 °C). The vehicle shall be approximately level during all phases of the test sequence. Drive wheel tires may be inflated up to 45 psi in order to prevent tire damage. These drive wheel tire pressures need to be reported with the test results. Fuels specified for emissions testing are intended to be representative of commercially available in-use fuels. Fuel tanks shall be filled to a minimum of 75% of available fill volume.

Test weight is determined at vehicle weight plus 300 pounds[530] and the equivalent test weight on the dynamometer is set in 125 pounds increments.[531] Vehicle preconditioning for chassis dynamometer testing consists of an initial one hour minimum soak and, one, two, or three driving cycles of the Urban Dynamometer Driving Schedule (UDDS) (*i.e.*, a cold start phase of 505 seconds followed by a cold stabilized phase of 864 seconds from the FTP-75), each followed by a soak of at least one hour with engine off, engine compartment cover closed and cooling fan off. Within five minutes after completion of the preconditioning drive, the vehicle shall be driven off the dynamometer and parked.[532]

The dynamometer run is conducted after a minimum 12-hour and a maximum 36-hour soak and has two stages. First, a UDDS (cold start plus cold stabilization phase from the FTP-75 driving schedule) is run, and then after 10 minutes a hot start phase from the FTP-75 is run.

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529 40 CFR § 86(B) prescribes test procedures for emissions testing. The information provided in this Section is a partial summary of the testing protocol, as it applies to diesel vehicles, and is not a complete recitation of the entire test procedures specified by the EPA.

530 CFR 40 § 86.129–00 "Road load power, test weight, and inertia weight class determination."

531 CFR 40 § 86.129–80 "Road load power, test weight, and inertia weight class determination."

532 40 CFR § 86.132-96, "Vehicle preconditioning."

These two stages constitute the FTP-75. Engine startup (with all accessories turned off), operation over the UDDS, and engine shutdown make a complete cold start test. Engine startup, after the 10 minutes soak described above, and operation over the first 505 seconds of the driving schedule completes the hot start test. Six particulate samples are collected on filters for weighing; the first sample plus backup is collected during the first 505 seconds of the cold start test; the second sample plus backup is collected during the remainder of the cold start test (including shutdown); the third sample plus backup is collected during the hot start test. Continuous proportional samples of gaseous emissions are collected for analysis during each test phase. For petroleum-fueled diesel-cycle vehicles, THC is sampled and analyzed continuously. Parallel samples of the dilution air are similarly analyzed for THC, CO, CO_2, CH_4, NO_x, and N_2O.

> *"During dynamometer operation, a fixed speed cooling fan shall be positioned so as to direct cooling air to the vehicle in an appropriate manner with the engine compartment cover open. In the case of vehicles with front engine compartments, the fan shall be squarely positioned within 12 inches (30.5 centimeters) of the vehicle. [..] The fan capacity shall normally not exceed 5,300 cfm (2.50 m^3/sec)."*[533]

The engine is started according to the manufacturer's recommended starting procedures in the owner's manual. The initial 20-second idle period begins when the engine starts. The transmission is placed in gear 15 seconds after the engine is started. If necessary, braking may be employed to keep the drive wheels from turning.

The SFTP test elements of aggressive driving (US06) and air conditioning (SC03) can be run immediately or up to 72 hours after the official FTP without refueling provided the vehicle has remained under laboratory ambient temperature conditions. If the time interval exceeds 72 hours or the vehicle leaves the ambient temperature conditions of the laboratory, the manufacturer must repeat the refueling operation.

For vehicles that include after-treatment systems that may periodically regenerate, manufacturers must propose a procedure for testing and certifying such vehicles. The proposal includes sufficient documentation and data to fully evaluate the operation of the after-treatment device and the proposed certification and testing procedure.

In order to verify compliance, the results of the test cycles are augmented by two adjustment factors: the intermittent regeneration adjustment factor (IRAF)[534] and the deterioration factor

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533 40 CFR § 86.135-12, "Dynamometer procedure."

534 40 CFR § 86.004–28, "Compliance with emission standards."

Please note that the light-duty regulation references the heavy-duty regulations when discussing regeneration. See 40 CFR § 86.1305–2010 "Introduction; structure of subpart." "Adjust emission results from engines using aftertreatment technology with infrequent regeneration events as described in § 86.004–28."

(DF).[535] IRAF is an additive term that accounts for the additional emissions generated during the DPF regeneration that occurs at intermittent intervals. Based on the emissions during an FTP drive cycle conducted while the DPF is actively regenerating, and after establishing how often a DPF regeneration will occur, the IRAF is calculated to account for the additional emissions that occur during the DPF regen. The DF is an additive term that accounts for the deterioration of the aftertreatment system and depends on the mileage of the vehicle. Therefore, a DF based on the mileage of the vehicle is added to the base test (i.e. the test during which no regeneration occurred) to verify that the vehicle remains compliant for the entire useful life of 150,000 mi. Obviously, if a vehicle is tested at 150,000 miles no DF is added since the vehicle is already fully aged but an IRAF is always added since regenerations occur at any age of the vehicle. The EPA also specifies the measurement and reporting of test results. The emissions threshold and test results are set for the entire cycle, not parts of the cycle. In other words, emissions are reported over the entire cycle and divided by the mileage driven to evaluate whether the vehicle passes the emission standard.[536] Instantaneous emissions, and emissions over individual segments of a cycle, are not reported and are not relevant to meeting the certification standard. As noted above, there are no maximum or "shall not exceed" emissions applicable to LDV.

13.3.2 **Test Cycles**

As mentioned above, the required emissions test cycles are the FTP, STFP (which includes the US06 and SC03 components), and HWFET. In addition, the EPA uses a cold temperature FTP test cycle, which sets a CO emissions standard for light-duty vehicles but does not specify an emissions standard for NO_x (or NMOG or PM) at cold temperatures.

13.3.2.1 **FTP Test Cycle**

The FTP-75 speed profile represents city driving conditions and is based on the Urban Dynamometer Driving Schedule. The FTP-75 profile consists of a full UDDS profile followed by a repetition of the first 505 seconds of the UDDS. By structuring the test in this way, the FTP-75 is composed of three segments or "phases," as shown in Figure E-6.:

I. Cold start phase, 505 seconds;
II. Stabilized phase, 864 seconds; and
III. Hot start phase, 505 seconds.

Emissions from each phase are collected in a Teflon bag, analyzed, and reported as g/mi or g/km. Full test emissions from these results are calculated using weighting factors of 0.43 for the cold start phase, 1.0 for the stabilized phase, and 0.57 for the hot start phase. The test

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535 40 CFR § 86.609–98 "Calculation and reporting of test results."

536 Test emissions results are weighted prior to calculating an emissions level to compare to the emissions standard. For example, for the FTP Test Cycle that I discuss in Section 1.3.2.1, full test emissions from these results are calculated using weighting factors of 0.43 for the cold start phase, 1.0 for the stabilized phase, and 0.57 for the hot start phase.

cycle average speed is 21.2 mph, the maximum speed is 56.7 mph, and the speed exceeds 50 mph for less than 11% of the cycle.

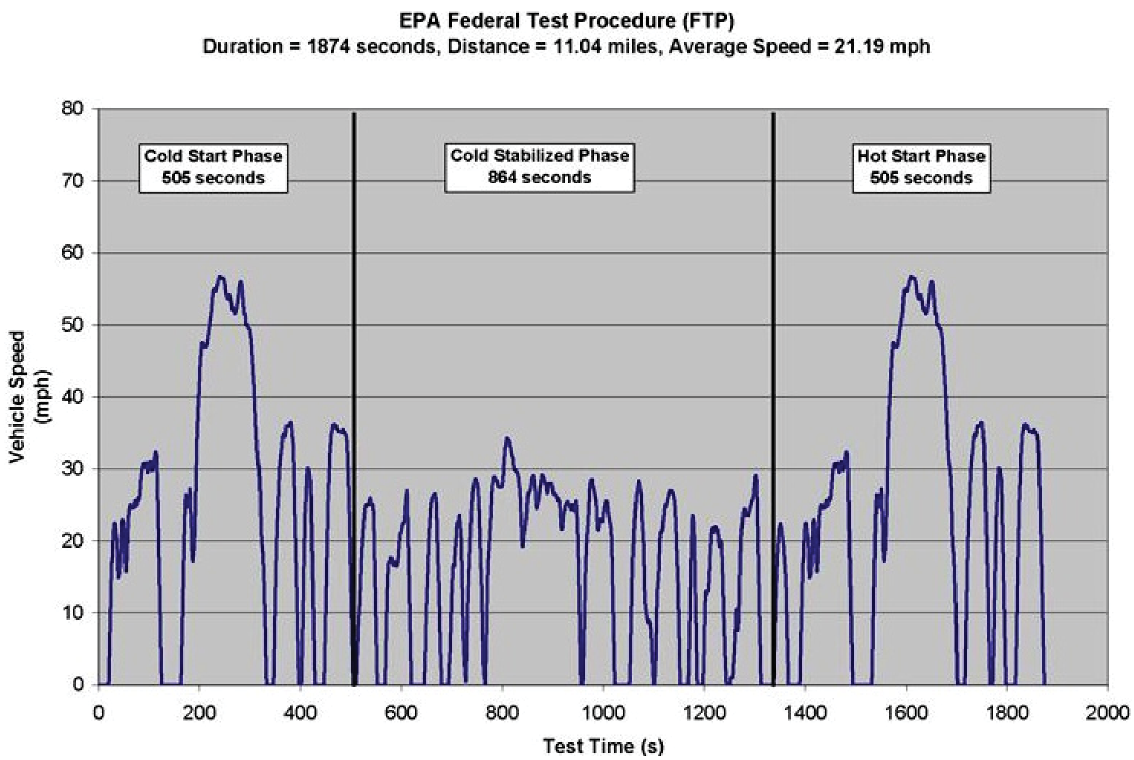

Figure E-6. Speed vs. Time plot, US EPA Urban Dynamometer Driving Schedule (FTP).[537]

13.3.2.2 Highway Fuel Economy Test Cycle (HWFET)

The HWFET speed profile is designed to represent highway driving conditions with speeds below 60 mph. The HWFET test cycle, shown below in Figure E-7, has an average speed of 48.3 mph, similar to the US06, but its maximum speed of 59.9 mph is lower than the US06.

The HWFET is run twice, consecutively, with a maximum break of 17 seconds between runs. The first run acts as a vehicle pre-conditioning sequence, over which emissions are not measured, while the second run is used for data collection and calculation of emission results.

537 "Dynamometer Drive Schedules," *Environmental Protection Agency,* available at https://www.epa.gov/vehicle-and-fuel-emissions-testing/dynamometer-drive-schedules.

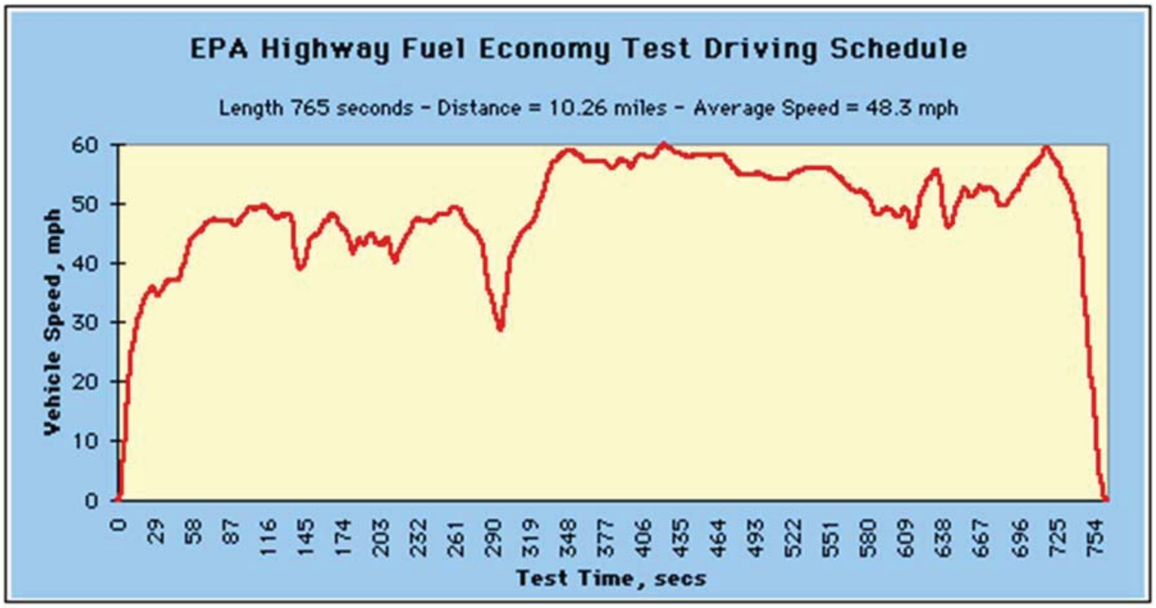

Figure E-7. Speed vs. Time plot, EPA Highway Fuel Economy Test Cycle (HWFET).[538]

13.3.2.3 Supplemental FTP Test Cycle (US06 and SC03)

The SFTP emission tests (US06 and SC03) and standards were developed to include driving conditions not fully represented by the FTP testing. The SFTP emissions standards combine (through a weighted average) the FTP emissions standards with US06 and SC03 test procedures, discussed further below.

The higher SFTP emission standards reflect the fact that emissions, including NO_x and NMOG emissions, are often higher when a vehicle is operated with high acceleration and high speeds (indicative of the US06 test cycle) or when a vehicle is operated at higher temperature and using the air conditioner (included in the SC03 test procedure).[539] Notably, the SFTP does not include a test procedure combining higher speed, higher acceleration, and higher temperatures together in one drive cycle. The EPA describes the reason for the SFTP:

> *"The SFTP standards are intended to better address and control emissions under driving conditions not captured when compliance with our FTP-based exhaust emissions standards is demonstrated, such as operation with*

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538 *Ibid.*

539 40 CFR § 86.158-00 ("The test procedure for emissions on the US06 driving schedule (see § 86.159-08) is designed to determine gaseous exhaust emissions from light-duty vehicles and light-duty trucks while simulating high speed and acceleration on a chassis dynamometer (aggressive driving). […] The test procedure for determining exhaust emissions with the air conditioner operating (see § 86.160-00) is designed to determine gaseous exhaust emissions from light-duty vehicles while simulating an urban trip […]").

> *the air conditioning turned on or driving at very high rates of acceleration and vehicle speeds (hereafter referred to simply as aggressive driving).”*[540]

The US06 portion of the SFTP was introduced to evaluate vehicle performance within the context of aggressive, high speed, and/or high acceleration driving behavior with rapid speed fluctuation, which were not addressed by the FTP test cycle.

During the development of the US06 test cycle, the EPA specifically addressed why extended high load events (described as road grade or acceleration events while trailer towing) were not included in the US06:

> *“EPA believes the infrequent nature of these extended high load events does not justify expanding control to address these events given the potential for significant catalyst degradation and/or the increased hardware cost.”*[541]

The US06 test cycle, shown below in Figure E-8, has an average speed of 48.3 mph and a maximum speed of 80.3 mph; the speed is over 70 mph for 23% of the cycle. The middle (highest-speed) portion of the cycle (between 150 and 470 seconds) averages 66 mph.

540 “Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements; Final Rule,” Federal Register, Vol. 65, No. 28, February 2000, p. 6730.

541 “Final Technical Report on Aggressive Driving Behavior for the Revised Federal Test Procedure Notice of Proposed Rulemaking,” EPA-420-R-95-102, January 1995, available at https://nepis.epa.gov/Exe/ZyPDF.cgi/P100P208.PDF?Dockey=P100P208.PDF.

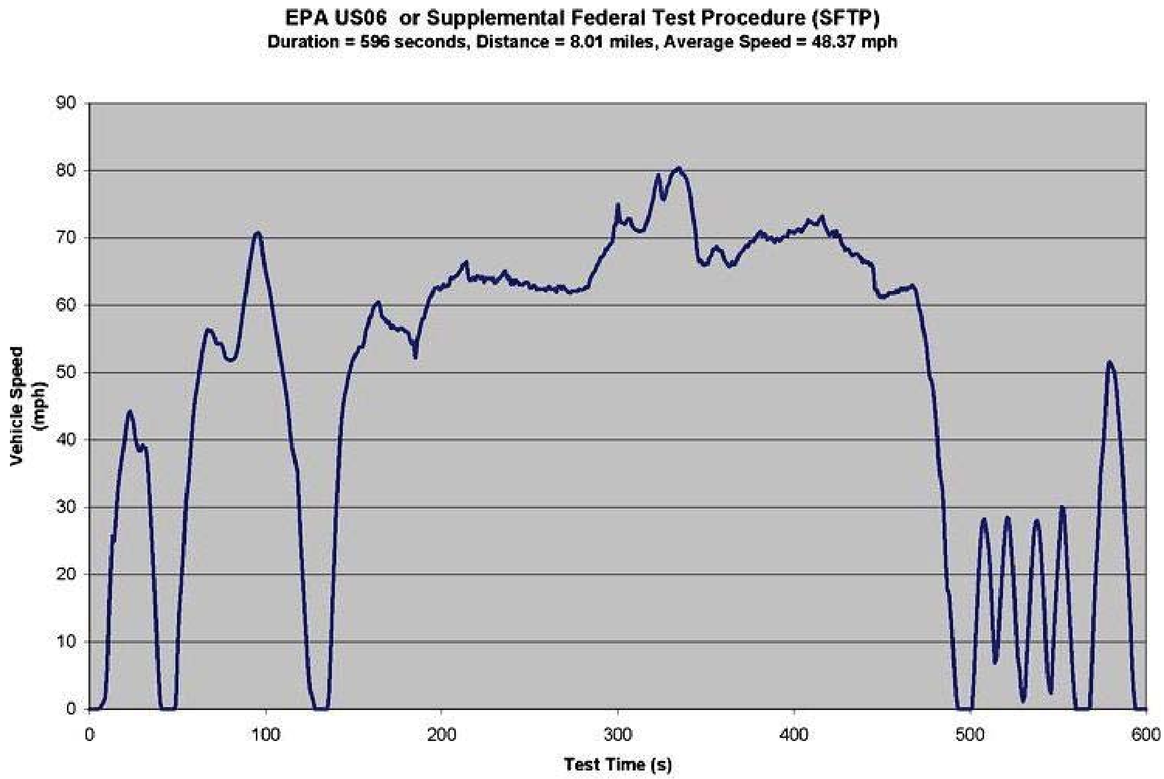

Figure E-8. Speed vs. Time plot, EPA Supplemental Federal Test Procedure (SFTP US06)[542]

The SC03 portion of the SFTP was introduced to evaluate vehicle emissions with the air conditioner operating and while simulating an urban trip during ambient conditions of 95 °F (35 °C).[543] The use of the air conditioner could add up to 5-6 kW to the road load for vehicles.[544] The SC03 test cycle, shown below in Figure E-9, has an average speed of 21.6 mph and a maximum speed of 54.8 mph, but only 3.5% of the cycle operates over 50 mph.

542 “Dynamometer Drive Schedules,” *Environmental Protection Agency,* available at https://www.epa.gov/vehicle-and-fuel-emissions-testing/dynamometer-drive-schedules.

543 Samuel, S., L. Austin, and D. Morrey, “Automotive test drive cycles for emission measurement and real-world emission levels-a review.” Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering 216, no. 7 (2002): 555-564 at pp.561-562 (“A new US emission test, the supplemental test procedure (SFTP) has recently been introduced in order to measure tailpipe emissions with the air-conditioning system operation. The research work of the National Renewable Energy Laboratory (NREL) of the USA shows that NO_x and CO more than double during the air-conditioning part of the SFTP.”).

544 Shete, Kaustubh. “Influence of Automotive Air Conditioning load on Fuel Economy of IC Engine Vehicles,” International Journal of Scientific & Engineering Research, Volume 6, Issue 8, August 2015, available at https://www.ijser.org/researchpaper/Influence-of-Automotive-Air-Conditioning-load-on-Fuel-Economy-of-IC-Engine-Vehicles.pdf.

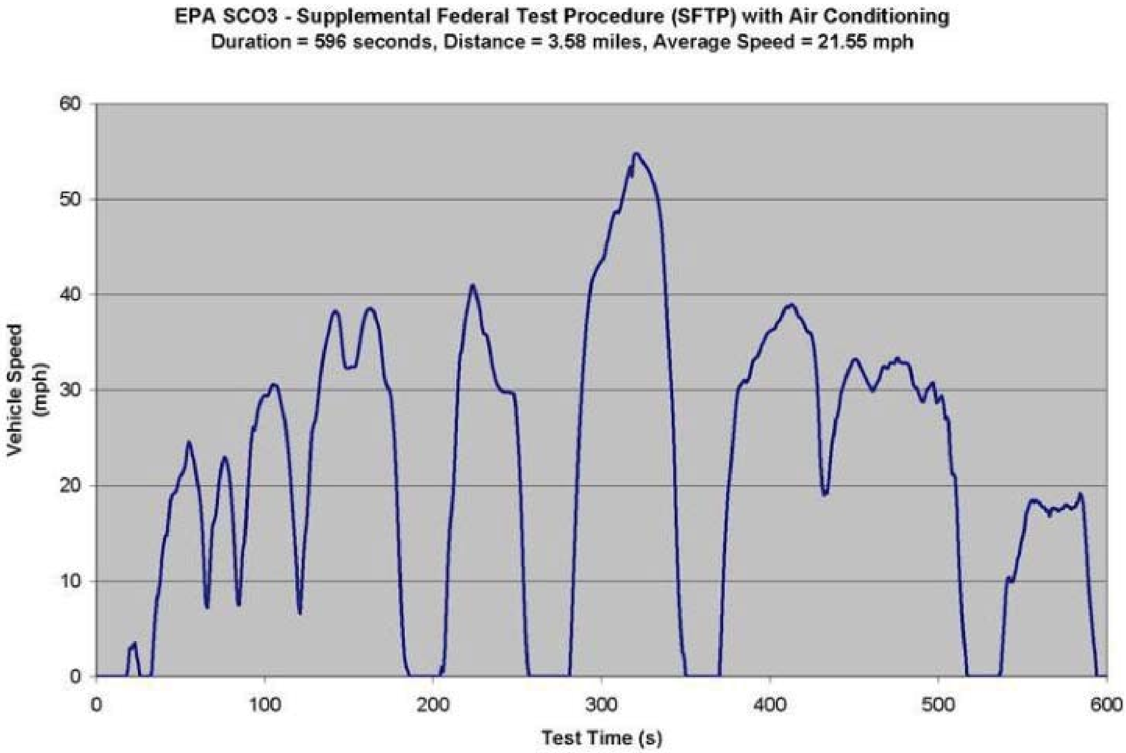

Figure E-9. Speed vs. Time plot, EPA Supplemental Federal Test Procedure (SFTP SC03).[545]

13.3.3 Portable Emissions Measurement System (PEMS) Testing

In contrast to dynamometer testing that takes place in a controlled laboratory environment, collecting emissions data during on-road driving requires the use of a vehicle emissions testing device called a Portable Emissions Measurement System (PEMS), with resulting data often referred to as real driving emissions (RDE).

A PEMS unit typically includes multiple elements, such as emissions analyzers, an exhaust flow measurement (EFM) device, a global positioning system (GPS), auxiliary sensors (for measuring ambient temperature and pressure, *etc*.), and a power supply.

Emissions are calculated per unit of distance based on signals from the analyzers, the EFM, and the GPS. The manuals associated with PEMS equipment provide installation and operation guidelines for the units. For example, the SEMTECH (a type of PEMS) user manual cautions users to "ensure that there are no leaks in the pneumatic plumbing from the

545 "Dynamometer Drive Schedules," *Environmental Protection Agency*, available at https://www.epa.gov/vehicle-and-fuel-emissions-testing/dynamometer-drive-schedules.

vehicle or engine exhaust output to the flow tube assembly,"[546] and a reference manual recommends a light weight lithium-ion battery pack for use as the power supply.[547]

PEMS units were first developed in the early 1980s; commercially available PEMS equipment was available by the 2000s, at which point the use of PEMS in the development of heavy-duty diesel vehicles had become common. But, to date, neither the EPA nor CARB have established guidelines approving or requiring the use of PEMS for official emissions testing for light duty-vehicles.[548]

The measurement uncertainty associated with PEMS equipment represents one of the main limitations of RDE emissions evaluations. The main sources of error are uncertainty in distance calculations, analyzer performance, and EFM readings. A comparison of a SEMTECH-D unit against traditional laboratory equipment using Constant Volume Sampling (CVS), used for emission certification testing, showed that the PEMS unit could have mass reading error up to 29% during a single FTP dynamometer run.[549] In a study commissioned by the European Commission to evaluate PEMS unit performance for RDE measurements, it was found that PEMS units typically utilized for light-duty vehicle RDE studies can introduce uncertainty up to 43% when all the sources of uncertainty are considered.[550]

In light of these results, and the additional sources of variability associated with on-road testing, the European Commission's Technical Committee – Motor Vehicle (TCMV) established a "conformity factor" equal to 2.1 for RDE evaluations.[551] This means that the "not to exceed" limit during on-road evaluations is currently set at 2.1 times the regulatory limit for dynamometer testing in Europe. The European Commission also required that the PEMS unit used for RDE evaluations be validated against a laboratory Constant Volume Sampling (CVS) measurement device, and produce results within ±15% or 15 mg/km of the CVS value (whichever is larger) before the PEMS unit could be used for RDE.[552] In addition

546 GMCOUNTS000853922 at 985.

547 GMCOUNTS000854175 at 219.

548 Ravi, Satya, "Comparison of In-use Emissions Measurement using PEMS, FTIR and Full-scale Dilution Method" (2017). *Graduate Theses, Dissertations, and Problem Reports*. 6484. https://researchrepository.wvu.edu/etd/6484

549 McConnell, Thomas G., "Simultaneous evaluation of multiple PEMS using an engine dynamometer emissions test cell" (2007). Graduate Theses, Dissertations, and Problem Reports. 4318 https://researchrepository.wvu.edu/etd/4318

550 Barouch Giechaskiel, Michael Clairotte, Victor Valverde-Morales, Pierre Bonnel, Zlatko Kregar, Vicente Franco, Panagiota Dilara, "Framework for the assessment of PEMS (Portable Emissions Measurement Systems) uncertainty,", Environmental Research, Volume 166, 2018, Pages 251-260, ISSN 0013-9351, https://doi.org/10.1016/j.envres.2018.06.012.

551 Commission Regulation (EU) 2016/646, L 109/6.

552 Commission Regulation (EU) 2016/427, L 82/38.

to the "conformity factor" of 2.1, the TCMV also established a factor of 1.6 to account for "extended" ambient conditions. These include "extended temperature conditions" between 28.4 ºF and 32 ºF (-2 ºC and 0 ºC) or between 86 ºF to 95 ºF (30 ºC and 35 ºC) and "extended altitude conditions." In other words, any emissions data collected in these "extended" conditions has to be adjusted down by a 1.6 factor, before being compared to the regulatory limit (which, itself, is adjusted by the conformity factor).

Similar provisions are present in the EPA on-road not-to-exceed (NTE) standards for heavy-duty vehicles in the United States. These include (but are not limited to) the following: the NTE emissions limit is applicable to data collected at altitudes below 5,500 ft (1,676 m) above sea level;[553] PM and NO_x emissions collected for temperatures below 55 ºF and above 95 ºF have to be corrected;[554] engines equipped with gas recirculation (EGR) are not subject to the NTE emission limits during certain cold operating conditions;[555] the NTE limit is 1.5 times the regulatory limit of 0.2 g/bhp-hr plus an additional 0.15 g/bhp-hr to account for PEMS accuracy bringing the effective in-use threshold at 0.45 g/bhp-hr which is 2.25 times the regulatory limit for dynamometer testing for heavy-duty vehicles.[556,557] Moreover, PEMS equipment verification against laboratory equipment is also regulated within the United States when PEMS measurements are used to verify heavy-duty "not to exceed" compliance.[558]

It should be also noted that as the emissions limits decrease, the evaluation of "not to exceed" thresholds as multiples of the regulatory limit become challenging because the baseline is a very small number.[559] For example, when considering Tier2 Bin5, the NO_x limit is 0.07 g/mi and the CO limit is 4.2 g/mi. A PEMS measurement error of 0.1 g/mi represents 143% of the NO_x limit but only 2% of the CO limit.

Further sources of variability in PEMS emissions values are attributable to the small sample size of vehicles tested and the inherent variability of on-road driving conditions. Should the

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553 40 CFR § 86.007–11 (B) (1)

554 40 CFR § 86.1370–2007 (e)(1)(ii). Specific correction factors to be determined by the manufacturer and approved by EPA.

555 40 CFR § 86.1370–2007 (f). The specific temperature threshold depends on intake manifold temperature or coolant temperature.

556 "In-Use Testing for Heavy-Duty Diesel Engines and Vehicles; Emission Measurement Accuracy Margins for Portable Emission Measurement Systems and Program Revisions", 40 CFR Part 86 [EPA–HQ–OAR–2004–0072; FRL–8539–3], Vol. 73, No. 50 / Thursday, March 13, 2008

557 CARB Mobile Source Control Division, "Heavy-Duty In-Use Testing (HDIUT)", Heavy-Duty Low NO_x Program Workshop, January 23, 2019

558 40 CFR § 1065.920 - PEMS calibrations and verifications.

559 Giechaskiel B., Clairotte M., Valverde V., Bonnel P., Real driving emissions: 2017 assessment of PEMS measurement uncertainty, EUR 29138 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-80384-0, doi:10.2760/127122, JRC109481.

specific vehicle(s) tested with the PEMS equipment not be representative of the vehicle population as a whole, the test results obtained by the PEMS equipment would be misleading. In addition, the same vehicle driven on the same route twice can show a significant difference in per-mile emissions depending on a variety of conditions, including weather and traffic conditions, differences in driving style between different drivers, the incidence of regeneration events, and so on.[560] Although these are inherently factors of experimental design, rather than the PEMS equipment itself, any use of PEMS equipment to compare vehicle emissions against a "not to exceed" limit should take these, and other sources of variability, into account.

The EPA and CARB have not established emissions standards or testing procedures or requirements to evaluate light-duty vehicles emissions using PEMS equipment, and current use of PEMS technology has been limited to the collection of data for informational and oversight purposes only. The only method currently used by EPA and CARB to establish emissions certification for light-duty vehicles is laboratory dynamometer testing. As I describe at length in Section 6.2 of my report, comparison of emissions standards to PEMS testing results is inappropriate, and any conclusions drawn from such comparisons are inherently unreliable.

13.4 Required Disclosures to Consumers

The EPA requires that certain information about a vehicle, including fuel economy and environmental ratings, be disclosed to consumers. The "Monroney sticker" is the informational label required by law to be affixed to the window of all new vehicles sold in the United States. It lists key pieces of information about the vehicle as well as standardized fuel economy values and environmental ratings.

The Monroney sticker originated in 1958 with the passage of the Automobile Information Disclosure Act, sponsored by Senator Almer Stillwell "Mike" Monroney. The act required that all new passenger vehicles distributed within the U.S. have a label that contained several key pieces of information, including:

(a) the make, model, and vehicle identification number (VIN),
(b) the final assembly location,
(c) the name and location of the dealer, and
(d) the manufacturer's suggested retail price (MSRP).[561]

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560 While in theory I agree with Mr. Smithers "that the same test cycle driven on the road or on the chassis dynamometer should produce the same results", however, in reality, given all the variability of operating conditions when testing on-road, it is nearly impossible to get the same results. *See* Smithers Report, ¶ 107.

561 The act was sponsored by Senator Almer Stillwell "Mike" Monroney. Chapter 28, Sections 1231-1233, Title 15 of the United States Code.

Congress and the EPA have expanded their labeling requirements and have made additional changes to the Monroney sticker over time.[562] Most recently, in 2011, and effective for model year 2013 and later vehicles, the National Highway Traffic Safety Administration (NHTSA) and the EPA published a joint final rule establishing new requirements for the disclosure of fuel economy and two environmental components of the Monroney sticker, hereafter referred to as the "2011 Rule."[563] These disclosures are presented in a fuel economy and environmental label affixed to the Monroney sticker, shown in Figure E-10 and discussed further below. Monroney label information can also be accessed at fueleconomy.gov for more detailed information about a vehicle's fuel economy and emissions.

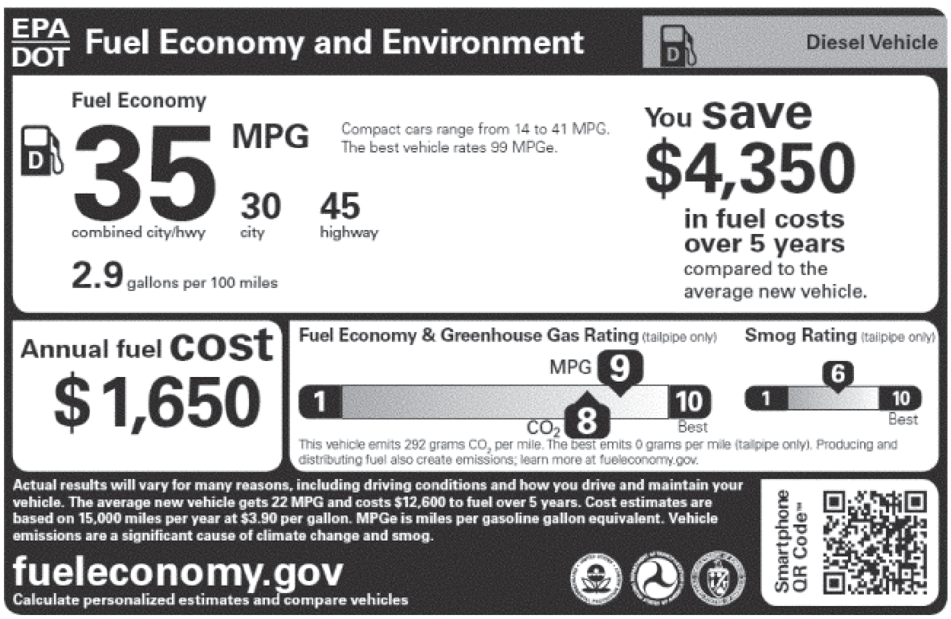

Figure E-10. An example fuel economy and environment label placed on the Monroney sticker of new diesel-fuel vehicles.[564]

13.4.1 Fuel Economy and Variability

In order to compare the fuel economy of one vehicle to another, the EPA implements standardized fuel economy tests (conducted on dynamometers) that are then reported on a vehicle's Monroney sticker. The required information includes the following:

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562 40 CFR §§ 85, 86, 575, 600.

563 Federal Register, Volume 76, No. 129, pp. 39478-39587.

564 Figure 3 of EPA: 40 CFR Parts 85, 86, and 600.

(a) fuel economy,
(b) estimated annual fuel cost,
(c) range of fuel economy for comparable vehicles, and
(d) any other relevant information authorized or required by the EPA.[565]

Over time, the EPA made various modifications to the label including adjustments to the fuel economy testing procedures, calculations, and label display. Since 1973, the U.S. EPA has published annual fuel economy ratings for new vehicles. The Fuel Economy Guide (which was originally called the "gas mileage guide") included results based on the FTP-75 city cycle only. In 1975, the results from the HWFET highway cycle were added.[566] Starting in 1976, the guide also included a combined city/highway fuel economy rating. Another update in 1976 was that manufacturers were required, under the Energy Policy and Conservation Act (EPCA), to apply a label on a side window indicating fuel economy for that vehicle (until then, manufacturers had been participating in the "Voluntary Fuel Economy Labeling Program").[567]

In 1984, the U.S. EPA introduced adjustment factors for purposes of labeling. The adjustment factors were 0.9 for the FTP-75 city cycle and 0.78 for the HWFET highway cycle, thus reducing fuel economy ratings by 10% and 22% respectively.[568]

Additionally, the EPA began to put a range of fuel economy values to give drivers a better sense of what they could expect. This change was put in place because of the variability in fuel economy during real-world driving due to various factors, such as driver behavior, vehicle trim options, and roadway characteristics. For both the city and highway fuel economy, the displayed lower and upper limits of fuel economy range were 85% and 115% of their displayed fuel economy.[569]

In 2006, the EPA issued their latest revision, and current methods for calculating fuel economy. Beginning in model year 2008, two options were presented for calculating a given vehicle's city and highway fuel economy. The first approach was the 5-cycle procedure, also referred to as the "measured" procedure. This procedure takes into consideration the fuel economy test results over five test cycles, including FTP-75, HWFET, US06, SC03, and cold temperature FTP-75. A single value for city and highway fuel economy is then determined by weighting the various tests and accounting for real-world driving conditions, such as road grade, vehicle load, and wind resistance. The second approach is referred to as the mpg-

565 "Energy Policy and Conservation Act"; Public Law 94-163, 89 Stat. 871, enacted December 22, 1975.

566 "1975 Gas Mileage Guide For New Car Buyers," EPA, September 1974.

567 "1976 Gas Mileage Guide For New Car Buyers," EPA, January 1976, Second Edition.

568 40 CFR § 600.307-86 (49 FR 13851, dated April 6, 1984).

569 *Ibid.*

based procedure, 2-cycle procedure, or "derived" procedure. This approach utilizes only the FTP-75 and HWFET test results for estimating fuel economy. An equation can then be used to convert the FTP-75 and HWFET fuel economy measures to an equivalent city and highway fuel economy value, respectively.[570]

Additionally, the 2006 EPA revision included expanding the fuel economy range shown on the Monroney Sticker. For model years 2008 and greater, the displayed lower and upper limits of fuel economy range were 83% and 117% of their displayed fuel economy.[571]

In 2007, a system was mandated for labeling new vehicles in the US with a rating for fuel economy and greenhouse gas and other emissions.[572]

13.4.2 Smog and CO_2 Ratings

In 2011, and effective for model years 2013 and later vehicles, the NHTSA and the EPA published a joint final rule for setting forth a rating system and establishing the current Monroney label. An example of the Monroney label under these new, and current, requirements is shown in Figure . The label added fuel cost estimates and a slider bar for comparing against all new vehicles of the same model year and removed the range in fuel economy altogether.[573] In addition to fuel economy, greenhouse gas and smog ratings are displayed on this revised label. The greenhouse gas rating was established based on 5-cycle CO_2 emissions and compares vehicles against other vehicles sold in the same model year using a 1-10 scale (10 being the best).[574] The smog rating was established in order to account for "other emissions." The agencies based this rating on currently regulated automobile emissions (NMOG, NO_x, PM, CO, and HCHO) and established a 1-10 scale (10 being the best). The smog rating given to a vehicle on this scale is determined by the vehicle's certification bin and model year.[575]

570 40 CFR Parts 86 and 600 – Fuel Economy Labeling of Motor Vehicles: Revisions To Improve Calculation of Fuel Economy Estimates; Final Rule, dated December 27, 2006.

571 40 CFR § 600.302-86 (71 FR 77949, dated December 27, 2006).

572 "Energy Independence and Security Act (EISA)," Public Law 110-140, 121 Stat. 1492, enacted December 19, 2007.

573 EPA: 40 CFR Parts 85, 86, and 600 & NHTSA: 49 CFR Part 575 – Revisions and Additions to Motor Vehicle Fuel Economy Label, dated July 6, 2011.

574 Greenhouse Gas Emissions Score. http://www.fueleconomy.gov/feg/emissions/GHGemissions.htm, accessed June 5, 2020.

575 Smog Rating. https://www.epa.gov/greenvehicles/smog-rating, accessed June 5, 2020.

Figure E-11. Example Monroney Sticker for a 2014 Chevrolet Cruze Diesel.[576]

Starting with model year 2013, the EPA requires additional information on the Monroney label and government websites related to the so-called "environmental performance" of the vehicle. This information included three metrics based on a relative scale from 0 to 10 associated with the MPG rating, the greenhouse gas (CO_2) emissions, and the smog emissions.

The CO_2 ratings reflect vehicle tailpipe emissions of carbon dioxide (CO_2), with vehicles scoring a 10 representing the cleanest alternative.[577] Since CO_2 is directly correlated to fuel consumption, the ratings for MPG and CO_2 are typically the same except for a few instances where rounding and the assignment of bins result in a vehicle having different MPG and CO_2 ratings.

How the rating is determined depends on the vehicle's model year because the rating is based on a relative comparison of the vehicle performance to other vehicles available on the market. For model year 2012 and earlier, EPA quantified greenhouse gases as a CO_2 equivalent value using the emissions factors presented in Figure E-12, while for later model years the CO_2 measurement was used directly to determine the rating. Figure E-13 and E-14

576 PLAINTIFFS000055

577 This rating only addresses emissions from the tailpipe, and therefore upstream emissions (from such activities associated with fuel production, transporting them to a processing plant, converting them into motor fuel, fuel distribution, etc.) are not included in this rating.

present the EPA tables used to calculate MPG and CO_2 ratings for model year 2009 through model year 2015 vehicles.

Table 1: Tailpipe CO_2e Emissions Per Fuel Type

	CO_2		CH_4 and N_2O
Fuel Type	Pounds/Gallon	Grams/Gallon	Grams/Mile
Gasoline	19.59	8,887[1]	1.9[2]
Diesel	22.44	10,180[3]	0.4[4]

1 Value is based on indolene fuel, a specific EPA test fuel.

2 U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*, Table A-90, EPA 430-R-09-004, April 15, 2009. Average value for Tier 2 passenger cars and light-duty trucks.

3 Value calculated based on 40 C.F.R. 600.113 carbon content.

4 U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*, Table A-90, EPA 430-R-09-004, April 15, 2009. Average value for advanced diesel passenger cars and light-duty trucks.

Figure E-12. EPA tailpipe emissions factors to estimate CO_2 emissions for gasoline and diesel vehicles.[578]

578 Greenhouse Gas Rating. *The Environment Protection Agency*. Available at https://www.epa.gov/greenvehicles/greenhouse-gas-rating.

MY 2014

Rating	MPG (gas)	CO_2 (g/mile)
10	>=43	<=209
9	35-42	210-258
8	30-34	259-301
7	26-29	302-349
6	23-25	350-395
5	20-22	396-456
4	18-19	457-508
3	16-17	509-573
2	14-15	574-658
1	<=13	>=659

MY 2015

Rating	MPG (gas)	CO_2 (g/mile)
10	>=45	0-200
9	37-44	201-243
8	31-36	244-291
7	27-30	292-335
6	24-26	336-378
5	20-23	379-456
4	17-19	457-539
3	15-16	540-613
2	14	614-658
1	<=13	>=659

Figure E-13. EPA tables to determine CO_2 and MPG ratings for MY2014 and 2015.[579]

The smog ratings follow a similar approach; vehicles are assigned a rating from 0 to 10 (10 being the cleanest available) based on the certification level. Ratings depend on the model year, according to the tables presented in Figure E-14 below.

579 Greenhouse Gas Rating. *The Environment Protection Agency.* Available at https://www.epa.gov/greenvehicles/greenhouse-gas-rating.

MY 2014 & MY 2015

Rating	EPA Tier 2	CARB LEV II	CARB LEV III
10	Bin 1	ZEV	ZEV
9	Bin 2*	PZEV	SULEV20/PZEV
8	Bin 2	SULEV II	SULEV30
7	Bin 3		ULEV70/ULEV50
6	Bin 4	ULEV II	ULEV125
5	Bin 5	LEV II	LEV160
4	Bin 6	LEV II option 1	
3	Bin 7		
2	Bin 8	SULEV II lg trucks	
1		ULEV & LEV II lg trucks	

Figure E-14. EPA tables to determine smog ratings for MY2014 and 2015

13.5 Variability in Fuel Economy Performance and Vehicle Emissions

The fuel economy achieved by a vehicle at any given time is highly dependent on driving conditions. Variability in fuel consumption, as with emissions, is influenced by a large number of factors including, but not limited to, environmental, vehicle, and driver-related factors. For a given vehicle, fuel consumption depends not only on the vehicle, but also on who is driving the vehicle, the conditions under which the vehicle is being operated, the use of accessories such as the air conditioner, and how that vehicle has been maintained. For these reasons, among others, the fuel economy of a vehicle is expected to vary significantly. Sticker fuel economy values, which are based on dynamometer testing, are therefore more appropriately treated as approximations or estimations of the real-world fuel economy an individual driver might experience in a given vehicle. The Monroney sticker contains a disclaimer that states "[a]ctual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle."[580]

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580 "Learn About the Label," *Environmental Protection Agency*, https://www fueleconomy.gov/feg/Find.do?action=bt1.

Variability in driving style has a large influence on fuel economy. These variables include differences in vehicle speed, acceleration intensity, braking behavior, and driving distance among others. For example, aggressive driving behavior (characterized by rapid acceleration, high speed, and heavy braking) can increase fuel consumption by 12-40% over "normal" driving.[581]

The route driven also impacts the fuel consumption experienced by a vehicle. Urban driving areas tend to have increased traffic density and traffic lights, which leads to more stop-and-go driving. As a result, fuel consumption can increase by 20-45% during rush hours. Fuel consumption during rush hour is particularly high on circumferential highways, such as the highway loops that surround many major U.S. cities, where vehicle speeds are low and accelerations are generally higher. Accordingly, fuel consumption can increase by 100% during these traffic conditions.[582] Elevation change along the driving route is another major cause of variability in fuel consumption. When traversing hilly routes, fuel consumption is higher due to increased power requirements when traveling uphill. As an example, fuel consumption has been found to be approximately 15-20% higher on hilly routes (gradient ranges from approximately –6% to 6%) when compared with flatter routes (gradients ranges from approximately –2% to 2%).[583] Other roadway factors influencing fuel economy are road curvature and road surface.

Environmental conditions also play a role in fuel consumption. Fuel economy is influenced by wind due to aerodynamic forces. Fuel economy is also lower during cold weather. This effect is exacerbated during shorter trips due to the time required to warm up the engine and run at higher efficiency.[584]

Vehicle maintenance contributors to fuel consumption include, but are not limited to, fuel quality, tire pressure, and wheel alignment. Other factors that can influence fuel consumption include vehicle loads and aftermarket modifications to the exterior of the vehicle. Specifically, the amount of power required to operate a given vehicle is directly dependent on the load being carried (or towed) and the amount of wind resistance due to external fixtures on that vehicle. This increase in power requirements translates to an increase in fuel consumption. As an example, roof racks, such as those used to carry bicycles, have been

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581 De Vlieger, I., D. De Keukeleere, and J. Kretzschmar, Environmental effects of driving behaviour and congestion related to passenger cars. Atmospheric Environment, 2000. 34(27): p. 4649-4655.

582 De Vlieger, I., D. De Keukeleere, and J. Kretzschmar, Environmental effects of driving behaviour and congestion related to passenger cars. Atmospheric Environment, 2000. 34(27): p. 4649-4655.

583 Boriboonsomsin, K. and M. Barth, "Impacts of road grade on fuel consumption and carbon dioxide emissions evidenced by use of advanced navigation systems." Transportation Research Record: Journal of the Transportation Research Board, 2009(2139): p. 21-30.

584 Eccleston, BH, and RW Hurn. "Ambient Temperature and Trip Length-Influence on Automotive Fuel Economy and Emissions." SAE Technical Paper, 1978.

estimated to be responsible for 0.8% of all fuel consumption nationally in the U.S. in 2015.[585] Additionally, mounting cargo on the roof can result in substantially lower fuel economy.[586]

13.6 Summary

In summary, vehicle manufacturers and regulators have established a formal, detailed, and specific process for certifying that vehicles meet the required emissions standards. NO_x emissions are one of many emissions that are part of the relevant standards. Vehicle manufacturers are required to meet standards for NO_x and other emissions across several different test cycles as specified by the EPA, and certification is based on laboratory test cycles, not with on-road testing. Vehicle manufacturers must meet these requirements in order to sell vehicles in the United States and must demonstrate ongoing compliance with these standards. Vehicle manufacturers are also required to disclose fuel economy standards and emissions ratings to consumers at the point of sale.

585 Chen, Y. and A. Meier, "Fuel consumption impacts of auto roof racks. Energy Policy," 2016. 92(Supplement C): p. 325-333.

586 Thomas, J., S. Huff, and B. West, "Fuel Economy and Emissions Effects of Low Tire Pressure, Open Windows, Roof Top and Hitch-Mounted Cargo, and Trailer." SAE Int. J. Passeng. Cars - Mech. Syst., 2014. 7(2): p. 862-872.